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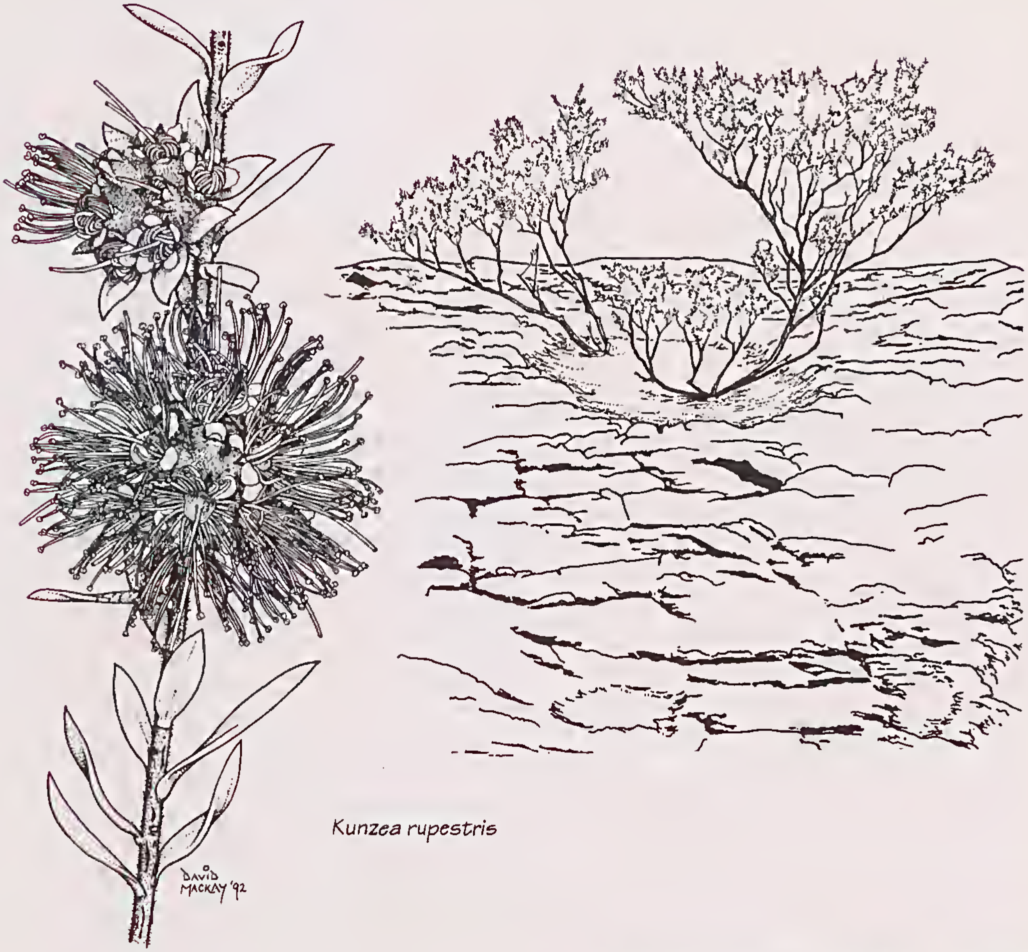

Kunzea rupestris

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Cover illustration
Kunzea rupestris (family Myrtaceae) on a rocky sandstone outcrop near Maroota in north-western Sydney. This endangered shrub species is known to occur at only a handful of sites. (See Penrith vegetation paper by D.H. Benson pp. 541–596).
Artwork: David Mackay

CUNNINGHAMIA

A journal of plant ecology

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The distribution, abundance and conservation status of *Grevillea beadleana* (Proteaceae): an endangered species

J.S. Benson

Abstract

Benson, J.S. (National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, Australia 2000) 1992. The distribution, abundance and conservation status of Grevillea beadleana: *an endangered species.* Cunninghamia 2(4): *503–521.* The two known disjunct occurrences of *Grevillea beadleana* (Guy Fawkes Lat. 30° 07´ S Long. 152° 19´ E and Binghi Lat. 29° 12´ S Long. 151° 45´ E) on the Northern Tablelands of NSW are documented for their population structure, edaphic features and associated plant species. *Grevillea beadleana* grows on granitic substrates with >75% silica content; derived soils are low in Mg, Ca, P and N. The abundance in three size classes at both populations (classified as seedling, young adult and mature adult) reflect recent fire history and subsequent recruitment. Seedling growth is highly susceptible to repeated fire and the species may have become rare due to increases in fire frequency over recent times. Death due to water stress during droughts may also limit numbers. Future research should centre on seed production, storage, viability and germination. This will refine management objectives regarding the optimal fire intensity and frequency for maintaining viable populations. In the interim, fire should be excluded from recently burnt areas for at least 15 years. Reservation (or protecting by other means) of the land on which the largest population occurs, at Oaky Creek Binghi, is necessary for the adequate conservation of the species.

Introduction

Grevillea beadleana McGillivray (family Proteaceae) is an attractive reddish-flowered shrub, growing on granitic outcrops in two locations on the Northern Tablelands of New South Wales. It was first collected in 1897 by Captain Crawford of 'Moona Plains' 30 km east of Walcha but searches of the granitic outcrops in this area, where it is presumed to have been first collected by Captain Crawford, have so far failed to re-locate the species (R. Makinson, pers. comm.). In 1981 it was rediscovered by N. Fenton (and collected in the same year by A.G. Floyd) on the rim of the eastern side of the Guy Fawkes River gorge inside Guy Fawkes River National Park. In 1988, another population was discovered by G. Roberts in the eastern section of the Binghi wilderness region, north of Torrington. The Guy Fawkes and Binghi populations are 115 km apart, separated by the Guy Fawkes River gorge system and the high altitude section of the New England Tableland between Glen Innes and Tenterfield, (Figure 1).

Grevillea beadleana is assigned a conservation status code of 2RC- in the Australian rare or threatened plant list (Briggs and Leigh, 1988). This has since been altered and its current threat rating is 3ECi (J. Briggs pers. comm.). The 3 implies the species extends over a range exceeding 100 km; E implies it is considered to be endangered with a serious risk of becoming extinct over the next few decades and Ci implies that it has less than 1 000 individuals in conservation reserves.

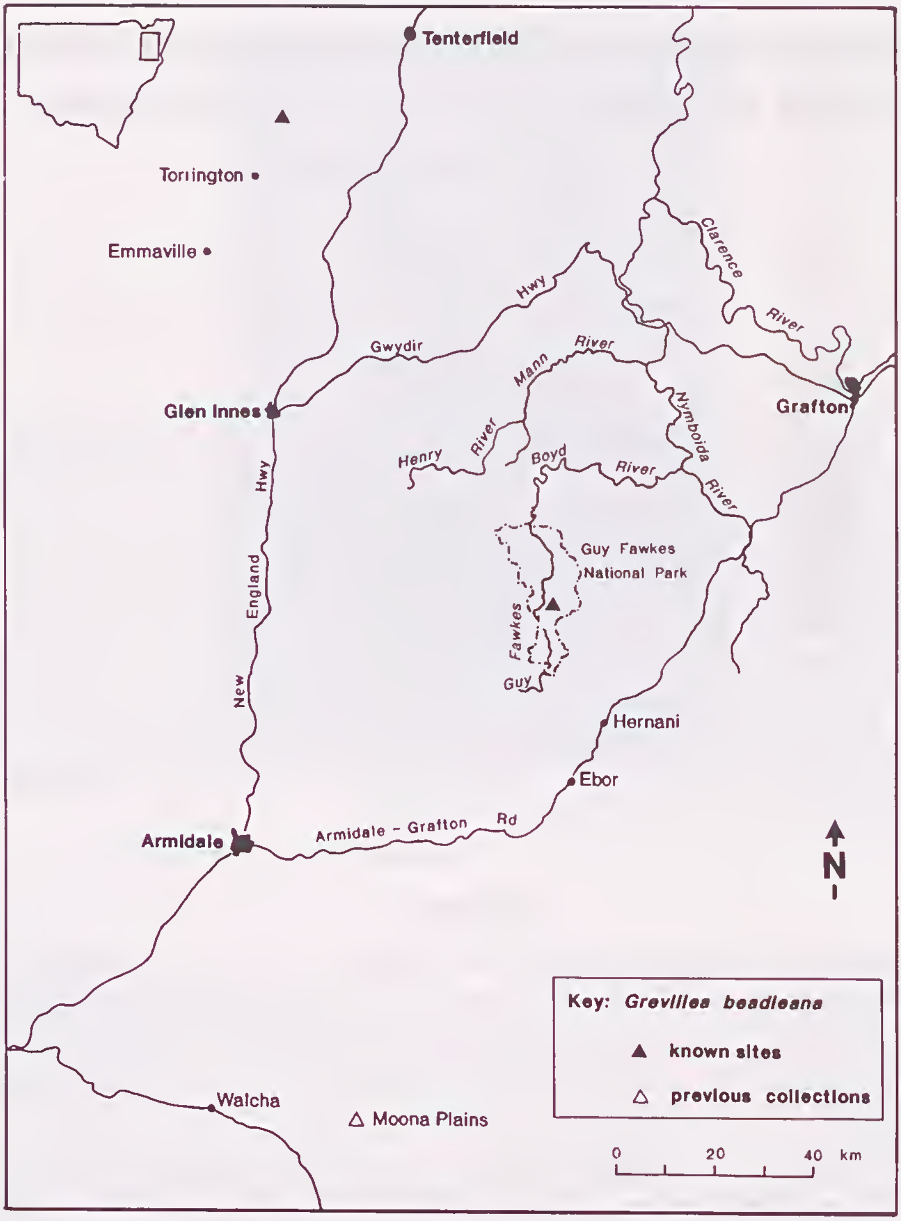

Figure 1. Recorded locations of *Grevillea beadleana*

Research of *Grevillea beadleana* has been limited to a field survey documenting its distribution, population size (including size classes as of 1991) and habitat (including associated plant species, soil and substrate).

While demographic studies are lacking, field survey data provide a basis for hypotheses about the causes of the species' rarity and current distribution.

Limited cultivation of the species has taken place at the Royal Botanic Gardens, Coffs Harbour Botanic Garden and a few private nurseries.

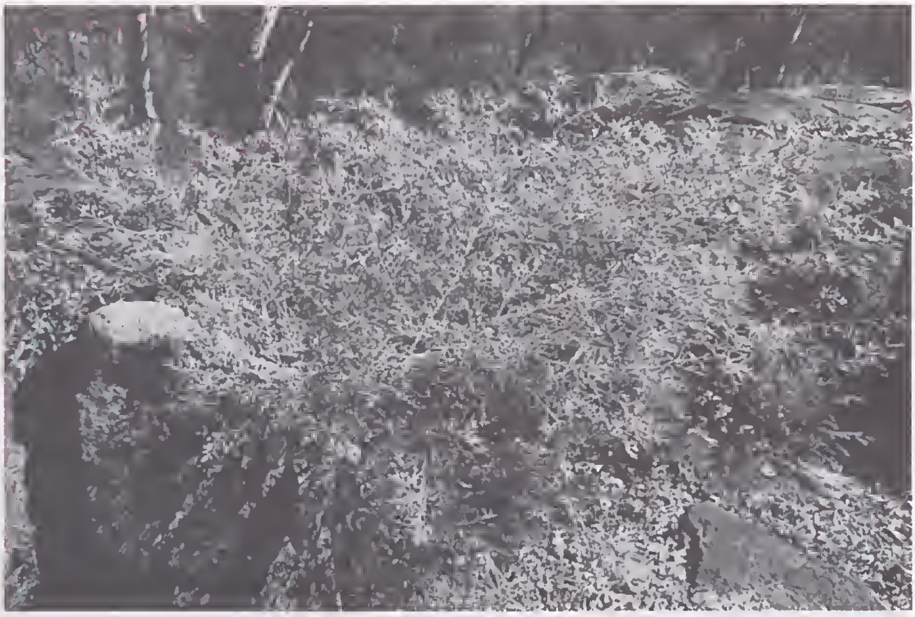

Figure 2. *Grevillea beadleana* is a robust shrub up to 2m high. The largest known population occurs along Oaky Creek, north of Torrington, on the western side of the Northern Tablelands.

Taxonomy

Grevillea beadleana is a spreading shrub up to 2 m high with divided, lobed, tomentose leaves 8–16 cm long and 5–10 cm wide (Figure 2). The reddish-purple flowers are aggregated in an erect 'toothbrush'-like terminal inflorescence (Figure 3). Flowering mainly occurs in late spring or summer but continues into early winter. The two-seeded fruits (follicles) are 10 mm x 6 mm coloured with brown to purple, longitudinal stripes. The seeds are about 5 mm long.

The first publication of the name *Grevillea beadleana* was in McGillivray (1986). This contains a minimal diagnosis. It is also described in Harden (1991). A full description of the species is included in a current revision of the genus *Grevillea* (McGillivray, in press).

McGillivray (in press) notes that the original collection from near Walcha in 1897 has broader and more sparingly divided primary leaf-lobes compared to the leaves of material collected at other sites but he still places it within the species *beadleana*.

Grevillea beadleana is placed in the 'toothbrush inflorescence' group of the genus Grevillea. Other related species in this group include *Grevillea willisii*, *G. caleyi* and *G. longifolia*, each of which is also listed as rare or threatened (Briggs & Leigh 1988).

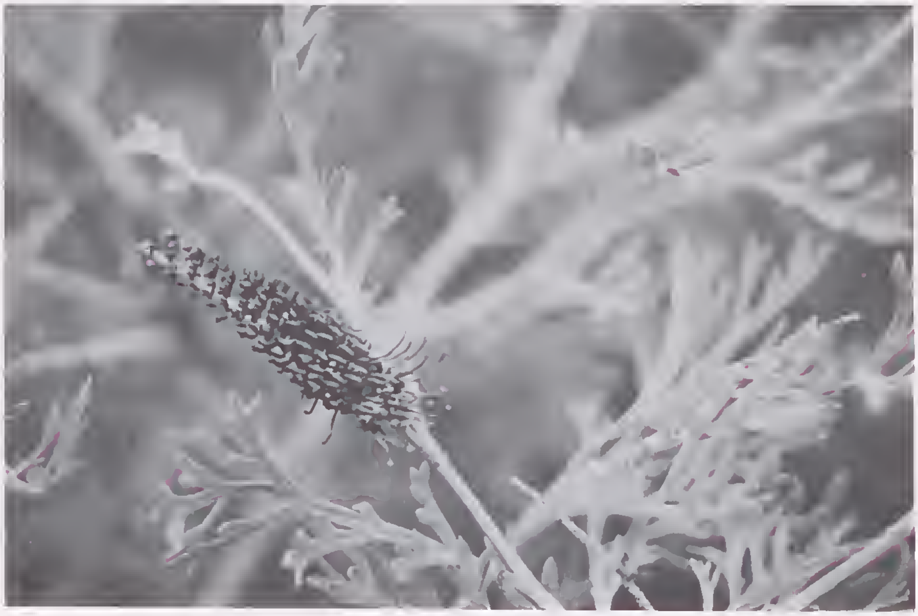

Figure 3. *Grevillea beadleana* mainly flowers in late spring and summer. It is placed in the 'toothbrush inflorescence' group of its genus.

Table 1. Herbarium collections of *Grevillea beadleana*..

Collector	**Coll. No.**	**Lat./Long.**		**Place**	**Date**	**F**
Capt. Crawford	Mel 75263			Moona Plains	1887	
A.G Floyd	AGF 1774			Guy Fawkes	15/10/1981	Y
J.B. Williams	NSW 151305	30° 00′ S	152° 20′ E	Guy Fawkes	13/06/1982	Y*
D.J. McGillivray	DJM 3993	30° 05′ S	152° 19′ E	Guy Fawkes	06/09/1982	Y
J.B. Williams	NE 48771A	30° 07′ S	152° 19′ E	Guy Fawkes	26/06/1988	
J.S. Benson	NSW 26879	29° 13′ S	151° 45′ E	Eastern Binghi	25/04/1989	Y

MEL - National Herbarium, Melbourne
NSW - National Herbarium, Sydney
NE - Herbarium of the University of New England
AGF, DJM - Personal collection number
F - specimen flowering
* - type collection

Methods

Using locality information from herbarium collections (Table 1), the known occurrences of *Grevillea beadleana* were visited. Nearby likely locations, chosen on the basis of aerial photographic interpretation and mapped geology, were also searched. These included Guy Fawkes Crags, 8 km north of the known location on the rim of the Guy Fawkes Gorge, and several granite knolls in the vicinity of Oaky Creek near Binghi. Floristic site data collected in the vicinity of Oaky Creek (Williams 1990) were reviewed.

The Binghi population occurs in two topographically distinct places - along Oaky Creek and on an unnamed knoll about 1 km to the west of the Creek. These subsets of the one population were sampled in April 1989 for associate species with six 20 x 20 m quadrats (five quadrats along the Creek and one on the knoll). During a second visit to the area in July 1991 the number of individuals of *Grevillea beadleana* on the knoll was counted, while estimates of the larger population along Oaky Creek were made using counts of the species in three 20 x 20 m quadrats. A count of the Guy Fawkes population was also made in July 1991.

Population counts were divided into three size classes with the view that these may have reflected several different aged cohorts arising from different germination events. Such events were most likely stimulated by fire but they could also have arisen during favourable climatic conditions. The size classes were: up to 40 cm (seedling), 40–80 cm (young adult) and greater than 80 cm high (mature seed-bearing adult). Other plant species in the quadrats were listed and assigned a cover rating using a modified Braun-Blanquet method.

Ten randomly collected sub-surface soil samples were taken from each of the populations at Guy Fawkes and Binghi (Oaky Creek). The samples from each site were mixed to gain an average sample for each site. This was tested for pH, electrical conductivity (EC), exchangeable cations of the elements calcium (Ca), magnesium (Mg) potassium (K), sodium (Na); nitrogen (N), sulphate (S), iron (Fe) and for exchangeable aluminium (Al) and phosphorus (P). Samples of rocks from the Guy Fawkes and Binghi sites were analysed for their mineralogy and major elements.

Measurements of slope, aspect and altitude were made at each site. Rainfall data from nearby stations were obtained from the Bureau of Meteorology.

Results

Grevillea beadleana is known from only two locations - Guy Fawkes and Binghi (Table 2). These two disjunct populations are described below.

Guy Fawkes

This occurrence is situated 45 km north of the town of Ebor, 3 km south-west of Chaelundi Mountain and 4 km south of Chaelundi Falls (Lat. 30° 05´ S Long. 152° 19´ E, altitude 950 m). It is accessible from the township of Hernani off the Grafton-Armidale Road via Marengo, Hardens and Misty Creek Roads.

The stand of *Grevillea beadleana* extends over an area of approximately 300 x 100 m (3 ha) downslope from the Escarpment Walking Track inside Guy Fawkes River National Park. Its habitat is a steeply sloping granitic bluff (Figure 4). The top section of the bluff adjoins an undulating plateau containing tableland species such as *Eucalyptus caliginosa* (New England Stringybark); the lower section contains some coastal plants, for example *Eucalyptus maculata* (Spotted Gum). Very few individuals of *Grevillea beadleana* survive away from the rock outcrop, either upslope or downslope.

Population

A total of 266 plants of *Grevillea beadleana* were counted at this location in July 1991. Nearly half of the individuals were seedlings. These grew over an area where adult plants had been burnt and killed in 1988. There was a dominance of mature adults in the unburnt section of the site. This partial burning of the site led to the overall population at the site being evenly divided between mature adults and seedlings (Table 3). Few young adults were recorded.

It was observed that many seedlings had established downslope from adult plants killed in the recent fire. The average height of these post fire seedlings was 20 cm. Sections of the cliff that were not burnt contained a small number of seedlings which may indicate there is limited germination in the absence of fire.

Substrate and soil

The outcropping granitic rock forming the bluff is silica-rich (>75%) leucocratic, feldspathic granite (R. Barnes, Geological Survey, Armidale, pers. comm.). This rock is part of a complex of granitic outcrops mapped as the Chaelundi Granite that outcrops over most of the plateau and gorge rim in the Chaelundi Mountain area. Its chemical constituency is dominated by silica and aluminium (Table 4). Minuscule levels of phosphorous and magnesium are present in the substrate.

The sandy-loam, skeletal soil derived from this highly siliceous substrate is poor in nutrients typified by a very low calcium and magnesium content. It also contains low levels of phosphorus and nitrate. In contrast, high levels of aluminium and iron are present due to the acidic pH and base unsaturates (Table 5).

Rainfall

Based on data collected at the nearby 'Marengo' homestead on the eastern side of the gorge (853 m, data recorded 1964–1976) and the 'Ponderosa' homestead on the drier, western side of the gorge (data recorded 1964–1974), the annual rainfall is estimated

Table 2. Location, altitude, aspect, slope, geology, soil, landform and tenure of *Grevillea beadleana* locations

Location	Lat/Long	Alt(m)	Asp.	Slope	Geology	Soil	L/form	Tenure
Guy Fawkes	30° 05' 152° 19'	950	290	40	Chaelundi granite	sand	upper slope	Nat. Park
Binghi Oaky Ck	29° 12' 151° 45'*	650	0	10	Mole Ck granite	fine sand	creek bank**	Crown lease
Binghi knoll	29° 13' 151° 44'	840	270	15	Mole Ck granite	sand	hilltop +slope	Crown lease

* The lat/long along Oaky Creek is set in the middle of this population which extends for 1.5 km.

** *Grevillea beadleana* mainly occurs on the eastern (westward facing) side of Oaky Creek.

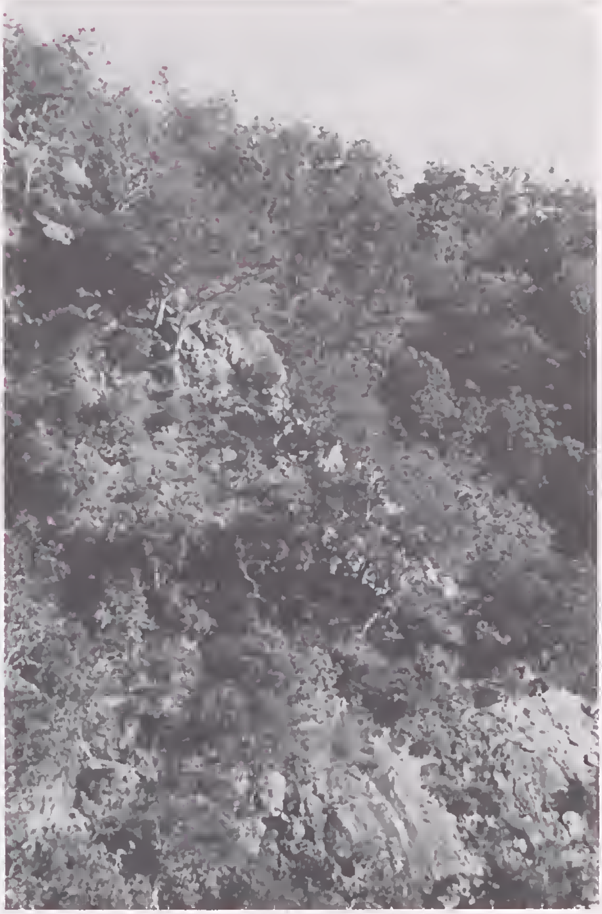

Figure 4. Protected from fire by its position on a granitic bluff, 266 plants of *Grevillea beadleana* were counted in 1991 on this granitic bluff on the rim of the Guy Fawkes River gorge inside Guy Fawkes River National Park. This is the only known conserved population.

to be approximately 1 000 mm (Figure 5). The rainfall is seasonal with three times as much falling in summer (November to February) than winter. Minimum rainfall is recorded in April, May and September.

Associated vegetation

Due to the predominance of rock outcrop the vegetation is woodland with a sparse shrub understorey. In the upper stratum *Eucalyptus campanulata* and the rare *Eucalyptus michaeliana* dominate with occasional small specimens of *Lophostemon confertus*. The middle stratum is dominated *Leptospermum novae-angliae, Allocasuarina littoralis, Grevillea beadleana* and *Notelaea microcarpa*. Scattered clumps of grasses, herbs and sedges make up the ground stratum with the most common plant species being *Gonocarpus teucrioides, Lepidosperma laterale, Poa sieberiana, Stipa ramosissima, Pomax umbellata* and a species of *Aristida*. A list of plant species recorded from the site is included in Table 6.

Table 3: Number of plants in size classes for *Grevillea beadleana* at its known locations (July 1991).

Location	Area (ha)	Population (% in brackets) <40 cm	40–80cm	>80cm	Dead*	Total alive
Guy Fawkes	3	127(48)	48(18)	91(34)**	NA	266
Binghi* Oaky Creek	15	67(2)	183(5)	3 410(93)	458	3 660
Binghi knoll	5	182(57)	25(8)	113(35)**	NA	320
Totals	23	376(9)	256(6)	3 614(85)		4 246

The Oaky Creek population was estimated from counts in three quadrats. Guy Fawkes and Binghi knoll populations were counted.

* dead plants from non-fire sources: only estimated for the Oaky Creek population.

** half of the population at these sites was burnt in 1988.

NA not assessed

Table 4. Major elements in rock samples

Element	Guy Fawkes (%)	Binghi (%)
SiO_2	77.40	76.60
TiO_2	.10	.13
Al_2O_3	13.15	12.65
Fe_2O_3	.17	1.33
MnO	.01	.03
MgO	.03	.08
CaO	.22	.13
Na_2O	4.00	3.25
K_2O	4.31	4.95
P_2O_{03}	.02	.03
S	.00	.00
LOI	.48	.40
Total	99.89	99.58

Table 5. Properties of surface soil samples (0-10 cm)

Location	Soil properties pH	Salinity (mS/cm)	Exchangeable cations Na	K	Ca	Mg	Ex Al*	Fe	S	N as (Nitrate)	P
Guy Fawkes	4.0	0.06	35	172	244	118	45%	107	78	0.9	5.0
Binghi	4.3	0.04	21	138	506	96	25%	66	58	0.3	2.0

Exchangeable cations and other elements expressed in ppm with the exception of exchangeable aluminium (Ex Al) which is given as a percentage of exchangeable cations.

pH is based on soil suspension in $CaCl^2$ solution.

Land-use history

Guy Fawkes River National Park was gazetted in 1972. Beforehand the area was vacant Crown land with licensed occupancies for grazing. Some of the forest above the gorge rim has been cleared in the past and has re-grown. The site where *Grevillea beadleana* occurs would have changed little since European settlement. It is included in an area that has been nominated as wilderness under the Wilderness Act 1987.

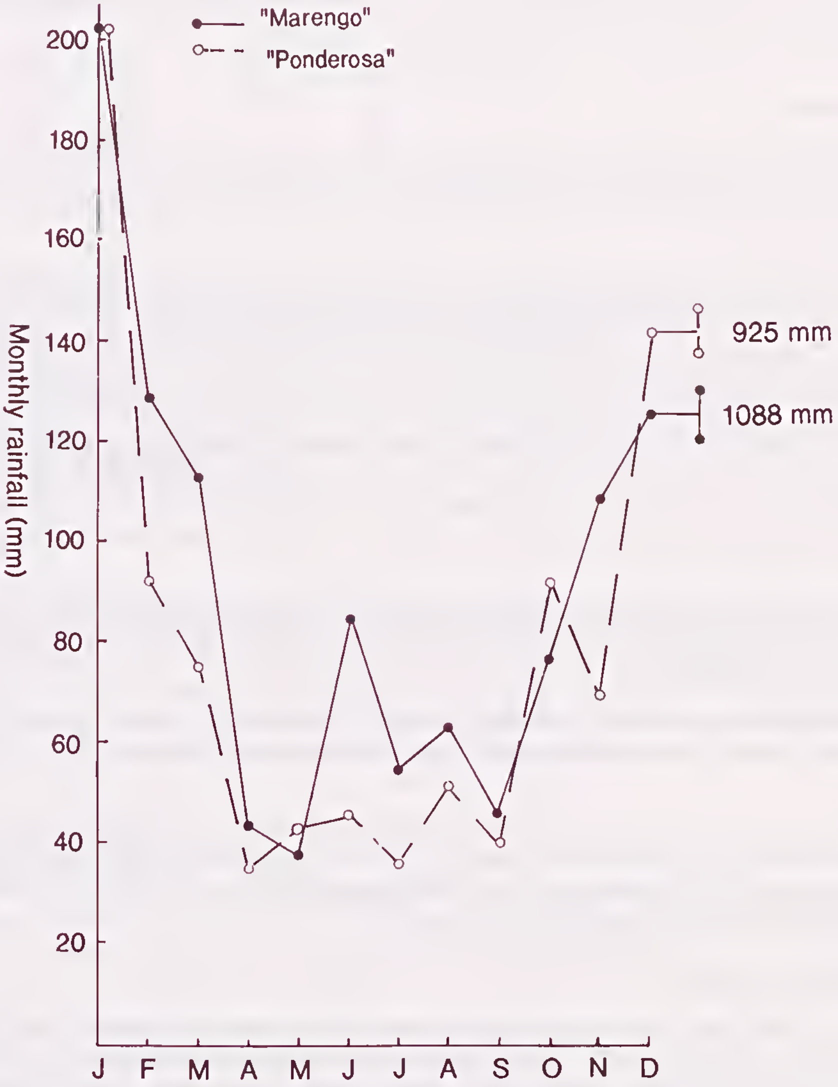

Figure 5. Mean rainfall for two stations in the vicinity of Guy Fawkes. Data supplied by the Bureau of Meteorology (1991).

Binghi

The Binghi population is distributed along a 1.5 km section of Oaky Creek (Lat. 29° 12´ S, Long. 151° 45´ E, altitude 950 m) and on a rocky knoll, 1 km to the west of Oaky Creek.

Unlike the situation at Guy Fawkes, where a steep bluff forms the habitat, the Binghi population occurs on undulating terrain, although there are some steep slopes adjoining the creek and the knoll. Most of the plants grow on a narrow strip of land within 100 metres of Oaky Creek. More plants are present on the eastern bank than the western bank. *Grevillea beadleana* grows on skeletal soil in crevices between granite outcrops which dominate the landscape.

Population

In July 1991, the population of *Grevillea beadleana* at Binghi was estimated to be approximately 4 000. Of this, 3 650 individuals were estimated to be distributed over 15 ha along Oaky Creek (Table 3) and 320 were counted over 5 ha on the knoll west of Oaky Creek.

The two subpopulations at Binghi have markedly different size class structures. More than half of the area of *Grevillea beadleana* on the knoll was burnt by a hot fire in 1988. This fire missed most of the plants along Oaky Creek. As a consequence, 57% of plants on the knoll were seedlings (Figure 7), in contrast with just 2% of the plants along the Creek. The Creek population is dominated by mature adults (93%).

Although there is no apparent physiographic difference between the creek banks of Oaky Creek, more plants were found on the eastern side compared to the western side. This distribution may be explained by the origin of fires in the west, possibly eliminating plants burnt before they could mature and set seed (see discussion below).

The two subpopulations at Binghi are growing in quite different topographical situations although they are only 500 m apart. It is possible that these subpopulations were once contiguous.

Despite searches of other knolls and creeks in the area by the author and others (Williams 1991) no other populations of *Grevillea beadleana* have so far been discovered.

Estimates taken for the Oaky Creek Binghi population reveal that 9% of the mature plants had died as a result of a drought in the early part of 1991. Many other individuals appeared to be suffering from water stress, indicating that this factor may be important in driving population fluctuations.

Substrate and soil

Mole Creek Granite is the major rock type in the area covering 40 000 ha. This granite is similar in its composition to the rock type at Guy Fawkes in having a >75% silica content, high aluminium levels and low levels of other elements (Table 4). However, it is relatively fine-grained compared with the Guy Fawkes granite and yields a fine loamy-sand soil. The soil is poor in nutrients illustrated by its low level of basic exchangeable cations - calcium and magnesium. Also, it is acidic, low in salts, nitrate and phosphorus but has a high exchangeable aluminium component (Table 5).

On flatter terrain away from the Creek, drainage is poor. The water table rises quickly to the surface after rain causing boggy conditions. *Grevillea beadleana* was rare here.

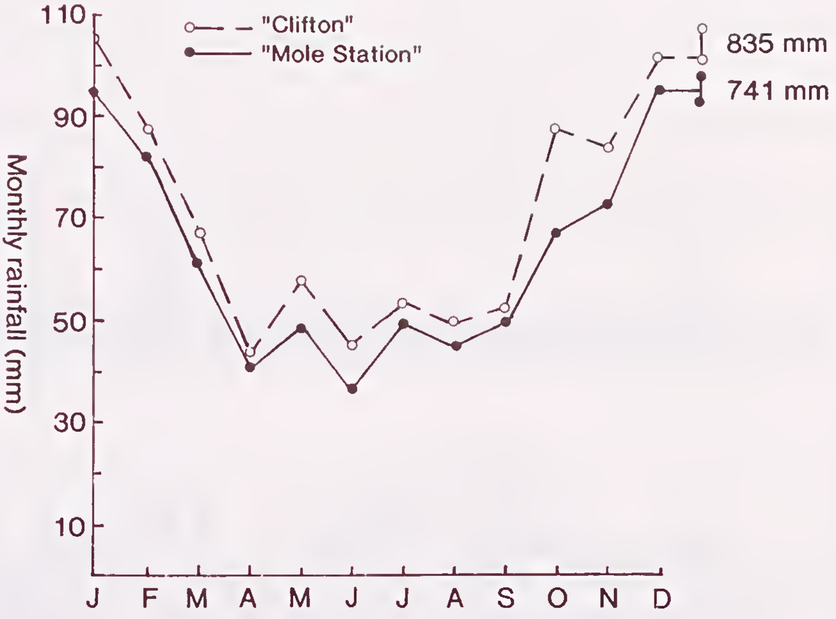

Figure 6. Mean rainfall for two stations in the vicinity of Oaky Creek, Binghi. Data supplied by the Bureau of Meteorology (1991).

Rainfall

Based on rainfall data recorded from nearby properties (Figure 6) the estimated annual rainfall in the Oaky Creek section of Binghi is approximately 800 mm (Bureau of Meteorology, 1991). 'Clifton' is located 20 km north of Oaky Creek at a similar altitude (670 m) (data recorded 1948–1990). 'Mole Station' is 10 km north of Oaky Creek at a lower elevation (440 m) (data recorded 1950–1990). The area is substantially drier than the Guy Fawkes site and probably has a higher evaporation rate due to higher average temperatures experienced at this lower altitude.

Associated vegetation

Vegetation structure is predominantly open-forest except along creek beds or on rock platforms where shrubs and forbs dominate. Common overstorey trees along Oaky Creek are *Eucalyptus prava, E. andrewsii, E. stannicola, Callitris endlicheri* and *Angophora floribunda*. On the knoll west of Oaky Creek *Eucalyptus andrewsii* is the dominant tree.

There is a diverse understorey flora with common shrub species including *Acacia granitica, Baeckea densifolia, Leptospermum brachyandrum, L. brevipes, Notelaea linearis, Mirbelia speciosa, Persoonia terminalis* subsp. *terminalis* and *Phebalium squamulosum*. Grasses, tussock forbs and sedges form a mid-dense ground cover. Common species include *Schoenus ericetorum, Xanthorrhoea glauca, Lepyrodia leptocaulis, Lomandra longifolia, Aristida armata, Cymbopogon obtectus* and *Eragrostis brownii*.

A combined plant species list from the *Grevillea beadleana* sites along Oaky Creek and on the adjacent knoll is given in Table 6.

Table 6. Plant species associated with *Grevillea beadleana*.

Species	Family	L	B	GF
Acacia sp. aff. falciformis	Fab.	S	1	
Acacia fimbriata	Fab.	S	1	
Acacia granitica	Fab.	S	2	
Acacia penninervis	Fab.	S	1	
Acacia pruinosa	Fab.	S	1	
#Acacia torringtonensis	Fab.	S	2	
Acacia viscidula	Fab.	S	1	
Adiantum aethiopicum	Adiant.	E	1	
Allocasuarina littoralis	Casuarin.	S	2	4
Alyxia ruscifolia	Apocyn.	S		2
Aotus subglauca	Fab.	S	1	
Angophora floribunda	Myrt.	T	3	
Aristida armata	Po.	G	3	
Aristida sp.	Po.	G		4
Arundinella nepalensis	Po.	G	2	
Astrotricha longifolia	Arali.	S	1	
Billardiera scandens	Pittospor.	C		1
Banksia integrifolia	Prote.	T		1
Baeckea densifolia	Myrt.	S	3	
Boronia anethifolia	Rut.	S		2
Brachycome tenuiscapa var. pubescens	Aster.	F	2	
Brachycome stuartii	Aster.	F	1	
Brachyloma daphnoides	Epacrid.	S	1	
Breynia oblongifolia	Euphorbi.	S		1
Callistemon sp. aff. pallidis	Myrt.	S	1	
Callitris endlicheri	Cupress.	T	3	
Calotis dentex	Aster.	F	1	
Cassinia quinquefaria	Aster.	S	2	
Cassytha glabella	Laur.	C	1	
Cheilanthes sieberi	Adiant.	E	2	2
Correa reflexa	Rut.	S	1	
Crassula pedicellosa	Crassul.	F	1	2
Cryptandra scortechinii	Rhamn.	S	1	
Desmodium varians	Fab.	C		1
Dianella caerulea	Dianell	F		2
Hibbertia acicularis	Dilleni.	S	1	2
Hibbertia obtusifolia	Dilleni.	S		3
#Hibbertia sp. aff. obtusifolia	Dilleni.	S	2	
Hibbertia riparia	Dilleni.	S	1	
Hovea longifolia	Fab.	S	1	
Hybanthus filiformis	Viol.	F	1	
Hypoxus hygrometrica	Hypox.	F	2	
Imperata cylindrica	Po.	G	2	
Isopogon petiolaris	Prote.	S	1	
Isotoma anethifolia	Lobeli.	F	1	
Jacksonia scoparia	Fab.	S	1	3
Lepidosperma laterale	Cyper.	G	1	4
Leptospermum arachnoides	Myrt.	S	1	
Leptospermum attenuatum	Myrt.	S	1	
Leptospermum brachyandrum	Myrt.	S	3	
Leptospermum brevipes	Myrt.	S	4	
Leptospermum novae-angliae	Myrt.	S		4
Leptospermum polygalifolium	Myrt.	S	2	
Lepyrodia leptocaulis	Restion.	G	2	
Leucopogon attenuatus	Epacrid.	S	1	
Leucopogon lanceolatus	Epacrid.	S		1
Leucopogon muticus	Epacrid.	S	2	
Liparis reflexa	Orchid.	F		2
Lobelia dentata	Lobeli.	F	1	
Logania albiflora	Logani.	S	1	
Lomandra confertifolia subsp. pallida	Xanthorrhoe.	TF	1	
Lomandra longifolia	Xanthorrhoe.	TF	2	3
Lomatia sialifolia	Prote.	S	1	
Lophostemon confertus	Myrt.	T		3
Maytenus silvestris	Celastra.	S		1
Melichrus urceolatus	Epacrid.	S	2	3
Mirbelia speciosa	Fab.	S	2	
Micrantheum hexandraum	Euphorb.	S	1	
Notelaea linearis	Ole.	S	2	
Notelaea microcarpa	Ole.	S	1	3
Olearia ramosissima	Aster.	S	1	

Species	**Family**	**L**	**B**	**GF**
Dianella laevis	Dianell.	F	1	
Cymbopogon obtectus	Po.	G	2	
Cymbopogon refractus	Po.	G	1	3
Davallia pyxidata	Davalli.	F		2
Daviesia umbellifera	Fab.	S	1	
Dendrobium speciosum var. *hilli*	Orchid.	F		1
Dodonaea viscosa	Sapind.	S	1	
Entolasia stricta	Po.	G	3	3
Eragrostis brownii	Po.	G	3	
Eucalyptus andrewsii	Myrt.	T	2	
Eucalyptus bridgesiana	Myrt.	T	1	
Eucalyptus campanulata	Myrt.	T		5
Eucalyptus caleyi	Myrt.	T	1	
Eucalyptus dealbata	Myrt.	T	3	
#*Eucalyptus michaeliana*	Myrt.	T		4
Eucalyptus microcorys	Myrt.	T		2
Eucalyptus moluccana	Myrt.	T	1	
Eucalyptus prava	Myrt.	T	3	
Eucalyptus stannicola	Myrt.	T	4	
Exocarpus cupressiformis	Santal.	S		2
Ficus rubiginosa	Mor.	T	1	1
Geranium neglectum	Gerani.	F	2	
Gahnia aspera	Cyper.	G	1	
Glycine clandestina	Fab.	C	1	
Goodenia hederacea	Goodenia.	F	1	
Goodenia rotundifolia	Goodeni.	F	1	
Gonocarpus teucrioides	Halorag.	F	2	4
#*Grevillea beadleana*	Prote.	S	4	4
Grevillea linearifolia	Prote.	S	2	
Hardenbergia violacea	Fab.	C		2
Olearia viscosa	Aster.	S		1
Opercularia hispida	Rubi.	F	1	1
Patersonia sericea	Irid.	F	1	
Petrophile canescens	Prote.	S	1	
#*Persoonia terminalis* subsp. *terminalis*	Prote.	S	2	
Persoonia sp. aff. *sericea*	Prote.	S		1
Phebalium squamulosum	Rut.	S	2	
Pimelea pauciflora	Thymelae.	S	1	
Plectranthus graveolens	Lami.	F		2
Poa sieberiana	Po.	G		3
Polyscias sambucifolia	Arali.	S		2
Pomax umbellata	Api.	F	1	3
Pomaderris lanigera	Rhamn.	S	1	1
Pomaderris prunifolia	Rhamn.	S	1	
#*Prostanthera staurophylla*	Lami.	S	1	
Ptilanthelium deustum	Cyper.	G	2	
Pultenaea foliosa	Fab.	S	1	
Pyrrosia confluens	Polypodi.	F		2
Solanum cinereum	Solan.	S	1	
Schoenus ericetorum	Cyper.	G	2	
Stackhousia muricata	Stackhousi.	F	1	
Stipa ramosissima	Po.	G		3
Stylidium larcifolium	Stylidi.	F	1	2
Themeda australis	Po.	G		3
Trema aspera	Ulm.	S		1
Wahlenbergia stricta	Campanul.	F	1	
Xanthorrhoea glauca	Xanthorrhoe.	TF	2	2
Xyris gracilis	Xyrid.	G	1	
Zieria cytisoides	Rut.	S	1	

KEY

B = Oaky Creek, Binghi including the knoll west of the creek (average cover rating from six 20 x 20 quadrats).

GF = Guy Fawkes National Park - Chaelundi; cover rating assigned to species over the area of distribution of *Grevillea beadleana* i.e 300 m x 100 m.

L (life-form): T = tree; S = shrub; F = forb; TF =tussock; F = forb; E = fern; C = climber.

rare or threatened on national or regional basis.

Cover ratings: 1 = <1%; 2 = 1–5%; 3 = 5–25%; 4 = 25–50% 5 = 50–75%; 6 = 75–100%.

Land-use history

Oaky Creek lies on the western side of the largest, naturally vegetated region on the Northern Tablelands of New South Wales - known as Binghi. The land tenure of the Binghi area is mainly Crown land and Crown lease and the main land uses are tin mining and rough grazing. It is one of the few areas on the western fall of the Great Dividing Range to have been classified as wilderness (Helman *et al.* 1976). Since the mid-1970s various proposals have been put forward to protect the natural features in the area. These have included establishing a national park, listing the area on the National Estate Register and declaring it as Wilderness (National Parks and Wildlife Service pers. comm., Australian Heritage Commission pers. comm, National Parks Association of NSW, 1976). The most recent report by the Department of Lands (1991) recommends that most of the Crown land in the Binghi area should be kept in Crown ownership and managed with the primary objective of maintaining its natural features. Such action would help prevent further clearing of native vegetation which is major threat to flora (including *Grevillea beadleana*).

Some abandoned tin mines are present in the area and there are traces of an old track running next to Oaky Creek - presumably related to mining earlier this century. Due to the rough topography, poor soils and the limited suitability of the vegetation as feed, grazing has been light.

Population biology

Field observations suggest that plants of *Grevillea beadleana* are usually killed outright when burnt. Lignotubers or similar root structures are absent and regeneration relies on the successful germination of seed and survival of seedlings. In a small number of cases, where the lower trunk has been protected from fire by rocks, suckering from the base of the trunk has been observed. It seems that given sufficent seed store the species will germinate well in the post-fire environment. There are no apparent limitations to pollination, although pollination vectors and mechanisms have not been studied.

Observations suggest that fruit do not persist on the plant but drop to the ground at maturity releasing their seeds. Large quantities of seed seem to be produced in both populations. The relatively heavy seed is unlikely to be dispersed far from its source.

The longevity of individual plants of *Grevillea beadleana* is unknown. A large specimen that was observed in 1981 at Guy Fawkes (J.B. Williams pers. comm.) was still alive in 1991 and must be at least 20 years old. It is likely that, left unburnt, individual specimens of *Grevillea beadleana* could live for several decades. In cultivation at Coffs Harbour Botanic Gardens plants grow quickly, flower in a year and produce viable seed within a maximum of three years (A. Floyd pers. comm.). Seeds remain viable in the soil for at least one year based on the time it took seedlings to emerge after the death of the only adult plant in the Coffs Harbour Botanic Gardens. This plant died after a prolonged wet period due to a fungal root infection (an incident that supports the view that *Grevillea beadleana* prefers better drained sites).

Care should be taken in extrapolating the Coffs Harbour observations to wild populations on the cooler tablelands where the growing season is shorter and habitat harsher than the coast. In its natural habitat the average height of seedlings two years after a fire was approximately 20 cm. From these observations it is estimated that, in its natural habitat, *Grevillea beadleana* may take up to five years to flower and seed.

Discussion

Along with many species in its genus, *Grevillea beadleana* favours well drained, acidic, low-nutrient soils - low in phosphorus, nitrate, calcium and magnesium but rich in silica and aluminium. Rainfall ranges from 800 mm to 1000 mm, altitudes from 950 to 650 m and aspect tends to be west to north-west.

The data confirm that *Grevillea beadleana* is a very restricted species. It also seems that given the limited number of collections, it was a restricted species at the time of European settlement. This supposition is based on a view that it is a highly attractive and distinctive plant - one which would not be easily overlooked by early collectors if it were widespread.

Though there is a potential large habitat for *Grevillea beadleana* in the Binghi area, recent botanical surveys covering lands around Torrington (Williams 1991) have failed to record it.

The rarity of *Grevillea beadleana* may be explained by historic and extant factors including changes in climate and detrimental fire regimes. From the historical perspective, *Grevillea beadleana* could now be surviving in climatic refugia. It may have been eliminated from other sites by extensive changes in climate over a long period of time and consequent competition with more adaptable species. This is supported by the fact that *Grevillea beadleana*, along with the also rare *Grevillea scortechinii*, are at the northern-most range of the *caleyi-longifolia-aspleniifolia* section of the 'toothbrush-inflorescence' group. Since there are related species in Western Australia it is possible that species in this group may have radiated from an ancient ancestor that lived perhaps as far back as 20–30 million years ago (R. Makinson pers. comm.). Also supporting this hypothesis is the apparent susceptibility of *Grevillea beadleana* to death from water stress during drought - a factor that may have eliminated the species from drier sites in the past.

If there has been a marked increased fire frequency in Australia (Singh *et al*. 1981) since human occupation, this may have had some impact on species which are sensitive to frequent fire. Most of the 'toothbrush-inflorescence' group of grevilleas may fall into this category. If so, this may form one explanation (yet to be tested) for the rarity of many of theses species today. *Grevillea beadleana* presently survives only in relatively fire-protected positions - on rocky platforms, between boulders or near creeks. Most of the Oaky Creek population occurs on the eastern side of the creek - perhaps the creek forms a buffer from fires that most frequently originate to the west. Similarly, the granitic bluff at Guy Fawkes protects surviving plants from most fires.

Even though the Guy Fawkes population is within a national park this has not diminished frequent fire. These come from both the west, running uphill from the Guy Fawkes River valley to the rim of the gorge and from the adjoining plateau, trickling down over the edge of the gorge. The recent fire in 1988 originated on the plateau and burnt several kilometres of forest understorey to the north and the south (J.B. Williams pers. comm.). Most fires in the area are illegally lit, presumably to enhance grazing. A Travelling Stock Route (TSR) adjacent to the Guy Fawkes River in the heart of the Park adds to the difficulties in controlling illegal grazing and associated burning off (G. Roberts pers. comm.).

Of particular interest are the apparent parallels in ecology and threatened status of several species in this 'toothbrush-inflorescence' group. For example, populations of the threatened *Grevillea caleyi*, which grow on lateritic ridgetops in the northern suburbs of Sydney, are susceptible to frequent burns (Scott 1986, A. Auld pers. comm.). Research on *Grevillea caleyi* suggests that fire should be excluded for at least 10 years to allow plants to mature, produce seed and build up a seedbank in the soil. Given that it seems to senesce after 30 years, occasional hot wildfire (say once every 20 years) may well be necessary for the successful survival of *Grevillea caleyi*. There is also some doubt about the effectiveness of a cool fire in promoting seed germination (A. Auld pers. comm.). The limited evidence on the ecology of *Grevillea beadleana* indicates that it may hold a similar reproductive strategy.

Fire, therefore, should not be viewed as incompatible with the existence of *Grevillea beadleana*. It would appear that it is vital to the regeneration of the species but is likely to be destructive if it occurs too frequently.

Other threats to the survival of *Grevillea beadleana* in the wild are habitat clearing, drought and grazing by sheep. In addition, its small population size at Guy Fawkes makes the species there vulnerable to the effects of inbreeding over the long term.

At Binghi there is the threat of physical disturbance of the habitat associated with the development of the leasehold land on which it grows. In 1989 some of the land on which *Grevillea beadleana* grows was illegally bulldozed by the lessee. Some plants of *Grevillea beadleana* were destroyed in the process and the disturbance resulted in localised soil erosion. Negotiations have since taken place between the lessee and relevant government authorities with a view to preventing further damage.

Another possible threat is grazing by goats. Several goat farms have been established on adjoining properties and if goats escape or were introduced into the naturally vegetated country, considerable damage could result (J.B. Williams pers. comm.). Any increase in grazing pressure, particularly on seedlings, could have an adverse impact on the populations of *Grevillea beadleana*.

Death of large numbers of individual plants during droughts is a possible important threat. Observations at Oaky Creek in July 1991 (Table 3) at the beginning of a major drought indicate this cause of mortality may be significant during dry times.

Future research

Specific research and management tasks have been outlined and costed in Benson (1991). Suggested projects include:

Additional survey: the Moona Plains locality should be re-surveyed in case *Grevillea beadleana* still exists there. Also, further botanical surveys in the Binghi granite area may locate additional populations.

Population dynamics: observations in 1991 revealed that at both its population sites, relatively large post-fire cohorts of *Grevillea beadleana* seedlings have survived for two years (Figure 7). Therefore it could be assumed that there are no major limitations with flowering, pollination, seed maturation and germination. Dispersal of the heavy seed appears to be limited to near the parent plant. However, experiments based on the tagging of both adult and juvenile plants would help substantiate the growth rates of the species, mean ages for the production of flowers and seed, seedling survival rate, longevity of individuals and mortality rates and causes. Research could also be warranted into seed viability, dormancy and response to heat and dispersal. Ants may play a role here because the seed is bordered by a waxy substance; similar seeds in related species are known to be gathered by ants (R. Makinson pers. comm.). To gain a better understanding of the fire regimes required to maintain populations, experimental burns of patches containing mature plants could be undertaken. Measurements should be taken of post-fire recruitment against the variables of temperature of the burn and post fire climatic conditions.

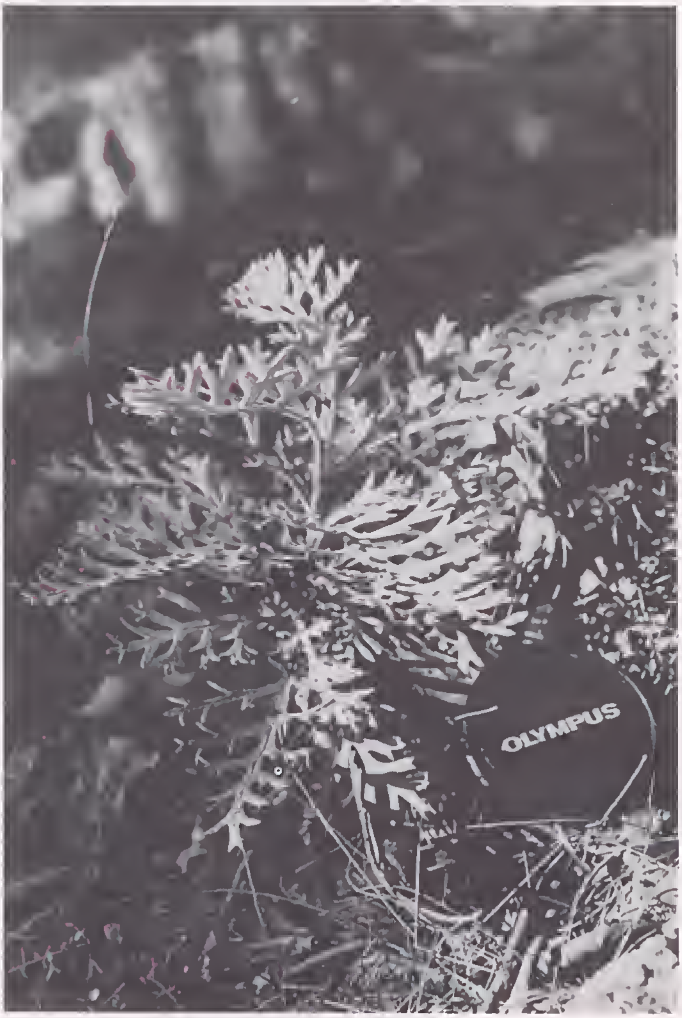

Figure 7. A two year old seedling. Parts of both the Guy Fawkes and Binghi populations of *Grevillea beadleana* were burnt in 1988. Adults are killed by fire and regeneration relies on seedlings.

Breeding systems: investigating the species' breeding system to establish its self compatibility and relative ratios of outcrossing to selfing would aid in indicating if inbreeding could be occurring in either or both of the populations.

Genetic variation: the presence of one large and one small population separated by 115 km allows for testing comparative differences in the genetic variability between the populations (R. Peakall pers. comm). The presence of any inbreeding in the smaller population could also be detected.

Conservation and management

Given that the species is endangered the main aim of management should be to maintain viable populations in the wild. This can best be achieved by preventing both populations from being burnt too often. It is inevitable that wildfire will burn each of the occurrences in the future, but every effort should be made to maintain a fire free period of at least 15 years (this suggested period is only an estimate at this stage pending the results of any future research into the species' fire ecology). The small population of *Grevillea beadleana* conserved in Guy Fawkes River National Park is in some ways the most threatened. It would seem that there needs to be better control on fires lit deliberately in the area including along the travelling stock route (TSR) in the valley. The removal of illegal livestock in the park, combined with the closure of the TSR could reduce some of the main incentives to start fires.

Protection of the large population of *Grevillea beadleana* at Oaky Creek, Binghi from inappropriate land use is a major management issue. This could be achieved either by acquisition of the land and its dedication as a nature reserve or by way of a secure covenant between the lessee and appropriate authority. Continuing destruction of nearby vegetation, construction of tracks and future recreational activities could adversely affect, indirectly or directly, this largest and most viable population of the species.

The protection of the habitat in the Oaky Creek valley would also benefit several other rare plant species - (*Prostanthera staurophylla, Hibbertia* sp. aff. *obtusifolia, Acacia torringtonensis, Acacia granitica* and *Persoonia terminalis* subsp. *terminalis*) and the *Eucalyptus prava-E. stannicola-E. andrewsii* plant association which is presently not represented in any conservation reserve.

If its population at Oaky Creek is conserved by way of a reserve or covenant and the appropriate authorities demonstrate they are able to control fire at both of its populations, then it would be justified to change the national threat status of *Grevillea beadleana* from endangered (E) to vulnerable (V).

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Distribution and abundance of *Blandfordia cunninghamii* Lindley (Blandfordiaceae)

C.L. Porter

Abstract

Porter, C.L.(Department of Applied Biology, University of Technology Sydney, P.O. Box 123, Broadway, Australia 2007) 1992. Distribution and abundance of* Blandfordia cunninghamii *Lindley (Blandfordiaceae). Cunninghamia 2(4): 523–532.* Distribution and abundance were compared in the rare *Blandfordia cunninghamii* and the more widespread *B. grandiflora* in the Blue Mountains of New South Wales. Environmental characteristics were studied at 13 sites. Approximately 750 plants of *B. cunninghamii* were found at 12 sites, nine of which are in conservation reserves. The habitat of *B. cunninghamii* is cooler and moister with more soil organic matter than that of *B. grandiflora.*

Introduction

Blandfordia cunninghamii Lindley (family Blandfordiaceae), one of four species in the genus, occurs in the Upper Blue Mountains and Illawarra regions of New South Wales. A rare species, it is coded 3RC- by Briggs & Leigh (1988), indicating some populations occur in conserved areas with the range exceeding 100 km, but the population size in reserves is unknown.

Another species, *B. grandiflora* R. Br., occurring in the Blue Mountains, has a more widespread range south from Fraser Island in Queensland to Sydney district.

The habitats of *B. cunninghamii* have damp soil (Beadle, Evans & Carolin 1982), and include hanging swamps at Kings Tableland, Wentworth Falls and Blackheath (Baker, Corringham & Dark 1984), rock ledges and in heath (Fairley & Moore 1989). Published localities for *B. cunninghamii* include: Blue Mountains, Mt Wilson, Wentworth Falls, Leura, Mt Kembla (Henderson 1987); Blue Mountains National Park; Illawarra State Recreation Area (Briggs & Leigh 1988); Wentworth Falls, Mt Tomah (Keith & Benson 1988).

The distribution and population size of *B. cunninghamii* and occurrence of *Blandfordia* species in the Blue Mountains were studied to confirm that populations are extant in the area, and to determine the range of communities and environments over which *B. cunninghamii* survives.

Methods

Distribution and population size

To confirm the distribution of the two *Blandfordia* species in the Blue Mountains, potentially suitable habitats were surveyed during summer 1989–1990, when the plants

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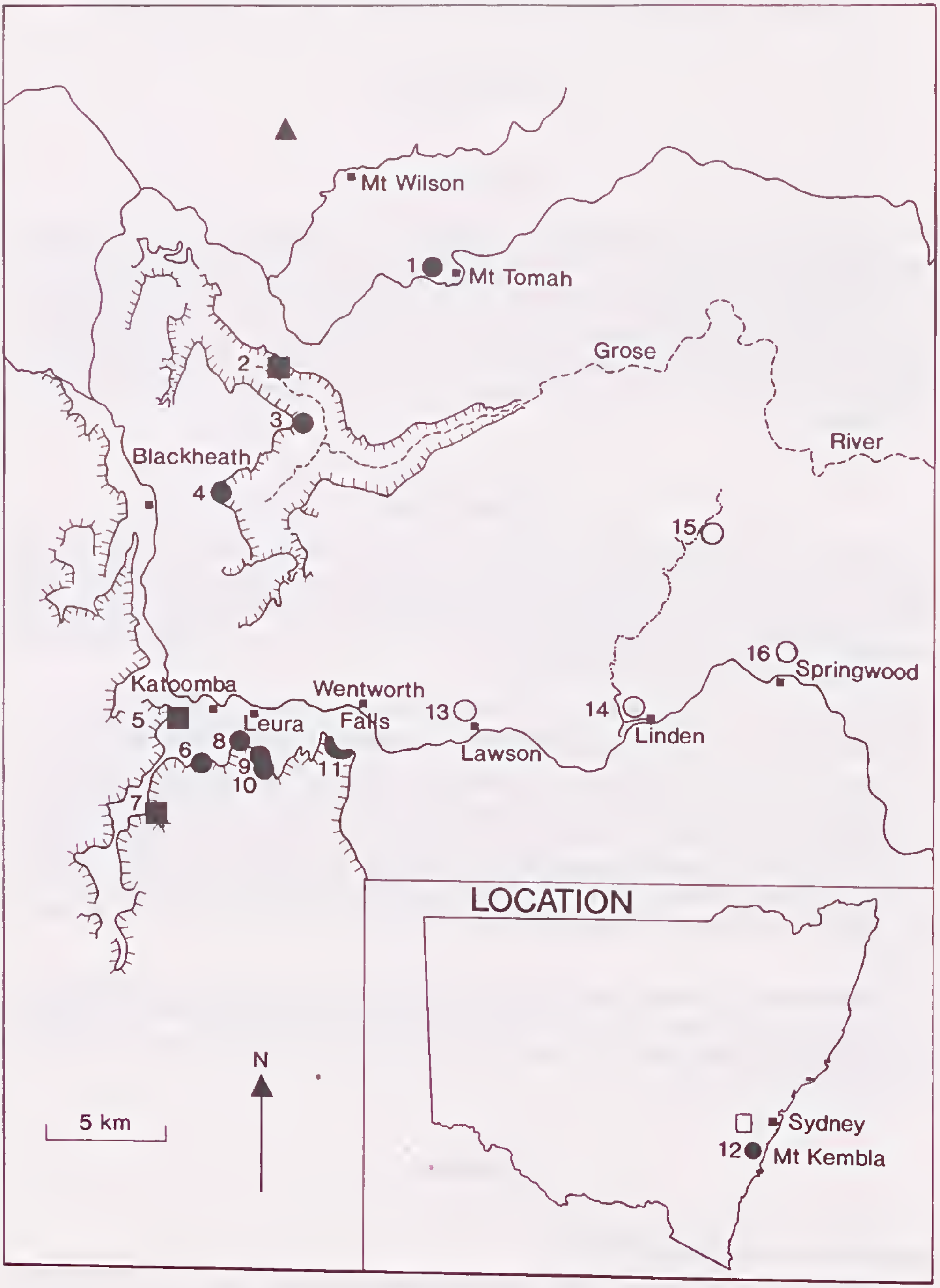

Figure 1. Distribution in the Blue Mountains of New South Wales of *Blandfordia cunninghamii*, localities confirmed (●); new localities (■) and prior collection locality not visited (▲) in this study; *B. grandiflora* (○) study sites. Localities listed in Table 1.

were easier to see if they were flowering. The survey was based on information about localities and habitats from herbarium specimens at the National Herbarium of New South Wales. Populations were counted in each site visited.

Site characteristics

Counting the plants in *B. cunninghamii* populations was difficult as individuals were often not distinctly separate but were in clumps of two or more. This was particularly so on rock faces where plants grew in a curtain of leaves, as at Mt Kembla. Typically *B. cunninghamii* plants were each approximately 30–50 cm in diameter and spaced 0.5–5 m apart. The area over which a population occurred was usually no more than 100 square metres. Most occurrences were on cliff edges, which affected the accuracy of counts.

Vegetative characters were often all that were available for identification of *Blandfordia*, as very few plants were flowering. Characters markedly associated with the particular species include: leaf margin crenulation, smooth in *B. cunninghamii* and crenulate in *B. grandiflora*; growth habit: *B. cunninghamii* leaves are laxer and *B. grandiflora* leaves have a distinct V-shaped cross-section. At a distance, it is difficult to differentiate *B. grandiflora* from juvenile *Xanthorrhoea* spp. and *B. cunninghamii* from *Lomandra longifolia* and occasionally from small, non-flowering *Gahnia* spp. (although *Gahnia* is scabrous). The leaves of *B. cunninghamii* are bright green and of similar width to those of *Lomandra longifolia* (though *B. cunninghamii* leaves are much longer and do not have a toothed leaf tip) and the leaf tips of *B. cunninghamii* are often necrotic. Numerous dark longitudinal veins (more obvious on the abaxial surface) along the length of the leaves is observed in *Blandfordia*. The number of veins ranges from 12–16 in *B. cunninghamii* and 6–10 in *B. grandiflora*.

Thirteen sites (nine populations of *B. cunninghamii* and four of *B. grandiflora*) representing the range over which the two species were observed were studied in detail in June 1990. At each site, attitude, aspect, slope and soil depth were recorded and three soil samples from the top 20 cm of the profile (excluding the A_0 horizon) were collected with an auger. Three replicates of each soil sample were analysed using the methods of Allen (1989) and pH, moisture content, organic content (estimated as % loss on ignition) and particle-size were measured. Site variation between the *Blandfordia* species in altitude, aspect, slope and soil depth was analysed by one-factor analyses of variance (Wilkinson 1987). Aspect data was transformed before analysis by subtracting 90° from each reading (and added after analysis). Variation in soil characteristics between-species in water content, loss on ignition, pH, % clay, % silt, % sand and % gravel was analysed by two-factor (*Blandfordia* species, site) nested analyses of variance (Wilkinson 1987) after averaging the replicate laboratory samples.

Associated species

Other vascular plant species rooted within one metre of each of three *Blandfordia* plants in the population were recorded. The pattern of plant species composition among the sites was analysed using hybrid multidimensional scaling (Belbin 1989). A two-dimensional ordination was used, with the Bray-Curtis dissimilarity measure, and a cut point of 0.8. The categorical nature of the pattern was tested using polythetic divisive clustering by indicator species analysis (Hill 1979).

Table 1. *Blandfordia* populations in the Blue Mountains: location, controlling authority of sites and estimated numbers of plants.

Site Number	Location	Control of land	Number of Plants (No. flowering 1989–1990)
1*	Mt Tomah	P.P.	20 (0)
2*	Pierces Pass	N.P.W.S.	45 (1)
3*	Blackheath	N.P.W.S.	40 (0)
4	Blackheath	N.P.W.S.	c. 30 (0)
5*	Katoomba-Cliff Walk	N.P.W.S.	25 (2)
6	Katoomba-Falls	B.M.C.C.	1 (0)
7	Katoomba-Narrow Neck	N.P.W.S.	3 (0)
8	Leura Cascades	B.M.C.C.	13 (0)
9*	Leura	N.P.W.S.	42 (0)
10*	Leura	N.P.W.S.	60 (0)
11	Wentworth Falls	N.P.W.S.	325 (0)
11a*	Wentworth Falls	N.P.W.S.	30 (0)
11b*	Wentworth Falls	N.P.W.S.	23 (0)
12*	Mt Kembla+	N.P.W.S.	100 (0)
13*	Lawson	N.P.W.S.	60 (1)
14*	Linden	B.M.C.C	200+ (1)
15*	Linden Ridge	N.P.W.S.	30 (1)
16*	Springwood	Crown Land	200+ (0)

* Denotes sites studied further; 1-12 *B. cunninghamii*, 13-16 *B. grandiflora*

+ Illawarra State Recreation Area

P.P. = Private Property; N.P.W.S = National Parks and Wildlife Service; B.M.C.C. = Blue Mountains City Council

Results

Distribution

The reported range of *B. cunninghamii* in the Upper Blue Mountains and at Mt Kembla was confirmed (Figure 1, Table 1). New locality records at Pierces Pass and Katoomba, also in the Upper Blue Mountains are indicated in Figure 1. Previously recorded sites of *B. cunninghamii* at Mt Wilson (specimen collected 1898) and at Yerrinbool (collected 1932) were not visited. Also one site reliably reported by R. Payne (in 1989) at Wedderburn could not be confirmed.

The occurrence of *B. grandiflora* in the Lower Blue Mountains was also confirmed. Based on personal observations and herbarium specimens, it is more widely distributed in the Lower Mountains than *B. cunninghamii* is in the Upper Mountains (note Figure 1 shows the study sites only of *B. grandiflora*).

The number of plants of *B. cunninghamii* within the boundaries of Blue Mountains National Park was approximately 620. Wentworth Falls contains 60% of these. The total number in all localities visited including Blue Mountains National Park was approximately 750 plants. Most of these plants (nine out of 12 populations) occur in areas controlled by the National Parks and Wildlife Service of New South Wales (Table 1).

Population size and flowering

Each population of *B. cunninghamii* was less than 100 plants (Table 1). For Site 11, all plants observed at Wentworth Falls were included (except 11a & 11b; two geographically separate populations used for study sites). This covers approximately two square kilometres and is comprised of numerous populations. *B. grandiflora* populations were generally larger, ranging from 30 to approximately 250 plants.

Three *B. cunninghamii* plants out of the total located (Table 1) flowered during summer 1989–1990 and none flowered during 1990–1991 (not shown on Table 1). More *B. grandiflora* plants were observed than *B. cunninghamii* plants to be flowering during 1989–90. The two sites in which *B. cunninghamii* flowered appeared to receive relatively high levels of solar radiation. At well-lit sites, such as along the National Pass at Wentworth Falls, leaves were generally broad with widths up to 15 mm, contrasting with plants in more shaded sites whose leaves were narrower.

Site characteristics

Examination of environmental data for the significance of the between-species variation (Table 2) indicate *B. cunninghamii* tends to occur at higher altitudes, on more southerly aspects and on steeper slopes than *B. grandiflora*, though Mt Kembla is of lower altitude. The soils at these sites are, as a result, more moist with higher organic content than the mostly north-facing *B. grandiflora* sites. Both species occur on acid soils. The most noticeable difference between sites of the two species is the sand content of their soils. Sand comprises approximately 80% of the soil on which *B. grandiflora* occurs, and between 50 and 75% for *B. cunninghamii*. Subsequently there is a higher proportion of silt and clay at sites where *B. cunninghamii* occurs.

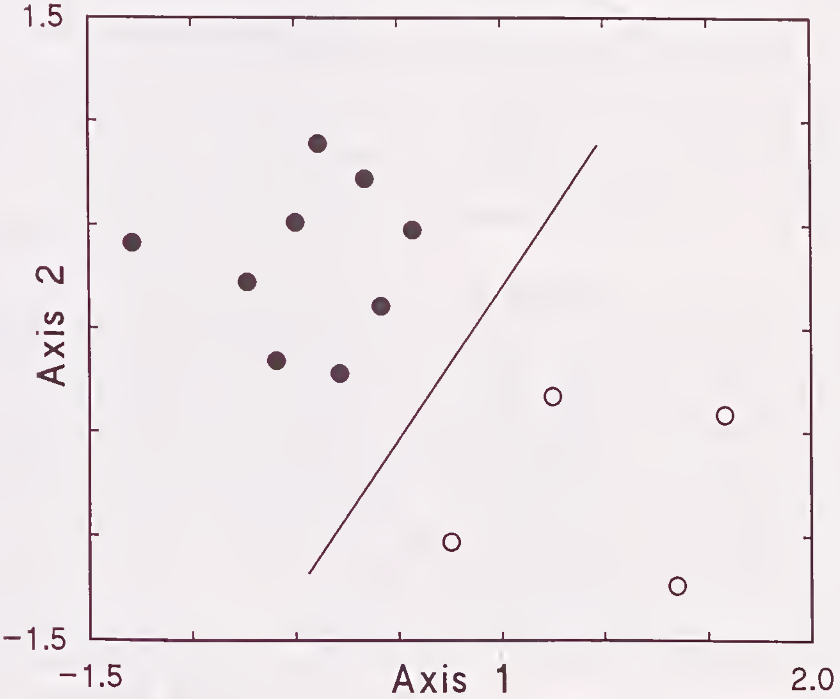

Figure 2. Two-dimensional hybrid scaling ordination of the plant species composition at the *Blandfordia cunninghamii* (●) and *B. grandiflora* (○) sites. The line indicates the principal division of the indicator species analysis.

Table 2. Average environmental characteristics at nine *Blandfordia cunninghamii* and four *B. grandiflora* sample sites

Environmental characteristic	***B. cunninghamii***									***B. grandiflora***				**Analysis of variance between-species**
	1	2	3	5	9	10	11a	11b	12	13	14	15	16	F
Site Characteristic														
Altitude (m)	920	670	720	960	900	880	820	820	500	680	530	520	330	10.57 *
Aspect (°)	216	204	162	135	160	130	216	216	186	20	10	344	200	20.23 *
Slope (°)	45	50	55	30	47	32	67	85	70	20	25	12	20	13.31 *
Soil depth (cm)	12	30	18	40	25	25	25	10	18	28	15	23	10	0.44 **
Soil Characteristic														
Total water content (%)	24.7	13.4	19.8	19.0	27.0	22.0	24.5	37.7	12.1	9.3	15.1	9.9	15.3	33.83 *
Loss on ignition (%)	15.1	6.7	6.8	8.9	9.5	5.4	7.3	15.2	7.7	2.8	8.4	3.7	5.7	27.22 *
pH	4.78	4.88	4.72	4.59	4.06	4.59	4.65	4.77	4.14	5.09	4.68	4.60	5.01	11.80 *
Gravel (>2.0 mm)(%)	3.6	51.4	11.1	11.1	9.1	2.9	2.4	4.8	7.2	7.7	3.3	2.0	4.3	3.59 **
Sand (0.05-2.0 mm)(%)	61.5	63.6	53.8	57.4	62.4	74.8	63.5	58.3	71.0	79.8	78.6	79.4	79.9	72.92 *
Silt (0.002-0.05 mm)(%)	14.1	17.6	24.6	14.8	19.0	9.9	15.4	19.8	13.7	7.9	8.0	7.3	8.5	65.74 *
Clay (<0.002 mm)(%)	24.4	18.8	21.5	27.9	18.6	15.3	21.1	21.9	15.3	12.3	13.4	13.3	11.5	25.79 *

Sand, silt and clay calculated as a percentage of non-gravel soil

* significant at $p<0.01$

** not significant at $p>0.01$

Localities listed in Table 1

Associated species

Ordination and clustering analysis of the floristic data (Figure 2) reveal two groups of sites. These correspond with the respective occurrences of the two *Blandfordia* species investigated thus indicating that each occurs with a distinct set of associated species. Of the 69 species recorded at more than one site (Appendix 1), 29 were recorded only at *B. cunninghamii* sites and eight only at *B. grandiflora* sites. Thus 46% of these widespread and common species occurred with both of the *Blandfordia* taxa. *B. cunninghamii* is associated with species commonly found in moist habitats, particularly damp rock faces, including *Acacia elata*, *Callicoma serratifolia* and *Ceratopetalum apetalum* in the overstorey, with an understorey of *Hakea dactyloides*, *Leptospermum polygalifolium*, *Stylidium productum*, *Dianella caerulea*, *Epacris pulchella*, *Gonocarpus teucrioides* and *Styphelia triflora*. *B. grandiflora* occurs with species more common in drier and more exposed areas often containing *Banksia serrata* in the overstorey, and an understorey of *Daviesia mimosoides*, *Entolasia stricta*, *Grevillea buxifolia* and *Platysace linearifolia*.

Two other rare plant species were found with *B. cunninghamii* at site 11a at Wentworth Falls, i.e. *Allania endlicheri* Kunth (Liliaceae), coded 3RCa (Briggs & Leigh 1988), growing on moist rock faces in the Blue Mountains and *Lomandra fluviatilis* (R.Br.) A.T. Lee (Lomandraceae), coded 3RC-. The latter species was not previously reported to occur on the Central Tablelands.

Discussion

The recording of distribution of *B. cunninghamii* in this survey was affected by access. All sites (except Sites 1 & 12) were located beside walking or vehicular tracks. Despite this, it is apparent that *B. cunninghamii* occurs at moist sites. Both species of *Blandfordia* are drought-tender (Bodkin 1986), but drainage may also be important to them, since all sites have some slope (Table 2). All *B. cunninghamii* sites have a significantly greater slope than *B. grandiflora* sites. This is inversely related to the sand content; the sand fraction is greater in *B. grandiflora* sites. The soils on which *Blandfordia* occurs in the Blue Mountains are mostly derived from sandstone, though *B. cunninghamii* was found also to occur on a sloping shale terrace at Pierces Pass (Site 2) and below the basalt cap of Mt Tomah (Site 1) where the plants are probably influenced by colluvium (second highest organic content (Table 2)).

Although two years is a short period to observe populations, it is clear that only very few plants of *B. cunninghamii* flower in some seasons at least. Low levels of seed set and germination may also be indicated in *B. cunninghamii* by the lack of juvenile plants. The exception was at Site 3 at Blackheath. This lack of juveniles may, however, be due to the recent absence of fire. Baker *et al.* (1984), state that *B. cunninghamii* 'occur in profusion after bushfires when the forest canopy is sparse'. In *Telopea speciosissima* and *Lambertia formosa*, flowering declines with time since the last fire after a peak approximately two years after a summer fire (Pyke 1983). In *B. nobilis*, peak flowering occurs one year after a fire (K.A. Johnson pers. comm.), and presumably this also occurs in *B. cunninghamii*. Plants of *Blandfordia* readily survive fire, as at Mt Tomah after a fire in 1976 (N. Rodd, pers. comm.). Although not documented, rapid growth with reproduction after fire in *Blandfordia* is almost certainly related to their underground rhizomes (Dahlgren, Clifford and Yeo, 1985). The longevity of *B. cunninghamii* plants is unknown, though from this survey it is clear that populations previously recorded are at least persisting.

Daviesia mimosoides was found to be a key associate of *B. grandiflora* as it occurred at the four sites studied in detail. Species with relatively high moisture requirement (Appendix 1) are indicators of probable presence of *B. cunninghamii* in the Upper Blue Mountains. These include *Hakea dactyloides*, *Leptospermum polygalifolium*, *Ceratopetalum apetalum*, *Callicoma serratifolia*, *Acacia elata* and *Smilax glyciphylla*.

At all *Blandfordia* sites exotic species are absent. The sites are mostly large distances from roads and picnic areas (minimal disturbance from external sources). Their low-nutrient soils generally do not provide good habitat for weeds. There is no perceived threat from exotic species to *Blandfordia* in the Blue Mountains.

Conservation

According to Briggs and Leigh (1988), for a species to be considered adequately conserved, there should be a minimum of 1 000 individuals in conservation reserves; conservation reserves in New South Wales being areas controlled by National Parks and Wildlife Service and the Forestry Commission. The known number of *B. cunninghamii* plants in conservation reserves is approximately 700. Hence, under the definition of Briggs and Leigh (1988), the conservation of this species remains inadequate (i). Surveys carried out shortly after fires may raise this status. It is unknown whether the single plant found at Katoomba Falls (Site 6) was originally part of a population that has diminished. The area of greatest concern is at Leura Cascades (Site 8) where there is severe trampling of the track edges, requiring some control of walking whilst retaining the aesthetic appeal of the area. Overall, however, the conservation status of *B. cunninghamii* is excellent, provided there is no further development in the escarpment/catchment areas of Wentworth Falls.

Acknowledgements

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APPENDIX 1

Average frequency of occurrence of plant species found in association with *Blandfordia*

Species	*B. cunninghamii*	*B. grandiflora*
PTERIDOPHYTES		
BLECHNACEAE		
+*Blechnum wattsii*	0.14	0.00
DENNSTAEDTIACEAE		
+*Hypolepis muelleri*	0.07	0.08
GLEICHENIACEAE		
+*Gleichenia rupestris*	0.11	0.08
+*Sticherus flabellatus*	0.07	0.00
LINDSAEACEAE		
+*Lindsaea microphylla*	0.04	0.08
ANGIOSPERMS-MONOCOTYLEDONS		
BLANDFORDIACEAE		
+*Blandfordia cunninghamii*	1.00	0.00
B. grandiflora	0.00	1.00
CYPERACEAE		
Caustis flexuosa	0.15	0.25
Lepidosperma laterale sens. lat.	0.11	0.17
Schoenus imberbis	0.00	0.17
IRIDACEAE		
+*Patersonia fragilis*	0.07	0.00
LILIACEAE		
Dianella caerulea	0.22	0.00
EPACRIDACEAE		
+*Dracophyllum secundum*	0.15	0.00
+*Epacris longiflora*	0.15	0.00
+*E. pulchella*	0.44	0.00
Leucopogon lanceolatus	0.07	0.00
Styphelia triflora	0.30	0.00
Woollsia pungens	0.04	0.25
ESCALLONIACEAE		
+*Quintinia sieberi*	0.15	0.00
EUPHORBIACEAE		
Amperea xiphoclada	0.22	0.08
FABACEAE-Mimosoideae		
+*Acacia elata*	0.11	0.00
A. terminalis	0.07	0.25
FABACEAE-Faboideae		
Bossiaea obcordata	0.00	0.17
B. scolopendria	0.00	0.17
Daviesia mimosoides	0.00	0.50
Dillwynia retorta	0.26	0.25
Gompholobium latifolium	0.07	0.00
Mirbelia rubiifolia	0.04	0.17
+*Pultenaea glabra*	0.11	0.00
P. scabra	0.11	0.25
GOODENIACEAE		
+*Dampiera stricta*	0.04	0.25
Goodenia bellidifolia	0.11	0.08
G. decurrens	0.33	0.17
HALORAGACEAE		
Gonocarpus teucrioides	0.33	0.08

Species	*B. cunninghamii*	*B. grandiflora*
LOMANDRACEAE		
Lomandra filiformis	0.07	0.00
L. gracilis	0.30	0.25
L. longifolia	0.04	0.17
L. obliqua	0.04	0.08
ORCHIDACEAE		
Terrestrial orchid	0.07	0.00
POACEAE		
Chionochloa pallida	0.41	0.17
Entolasia marginata	0.22	0.33
E. stricta	0.00	0.33
SMILACACEAE		
Smilax glyciphylla	0.19	0.17
XANTHORRHOEACEAE		
Xanthorrhoea sp.	0.15	0.00
ANGIOSPERMS-DICOTYLEDONS		
APIACEAE		
Platysace linearifolia	0.15	0.50
Xanthosia pilosa	0.22	0.08
X. tridentata	0.19	0.08
ASTERACEAE		
Olearia erubescens	0.15	0.00
CASUARINACEAE		
Allocasuarina littoralis	0.07	0.00
CUNONIACEAE		
+*Callicoma serratifolia*	0.15	0.00
+*Ceratopetalum apetalum*	0.19	0.00
MYRTACEAE		
+*Baeckea linifolia*	0.04	0.08
Leptospermum polygalifolium	0.41	0.33
L. trinervium	0.22	0.00
+*Tristaniopsis collina*	0.15	0.00
PITTOSPORACEAE		
Billardiera scandens	0.11	0.08
POLYGALACEAE		
Comesperma ericinum	0.11	0.00
PROTEACEAE		
Banksia ericifolia	0.11	0.00
+*B. marginata*	0.19	0.00
B. serrata	0.00	0.17
Grevillea buxifolia	0.00	0.25
G. sericea	0.00	0.17
+*Hakea dactyloides*	0.30	0.00
Lambertia formosa	0.04	0.08
Lomatia silaifolia	0.07	0.00
Persoonia laurina	0.07	0.00
+*Symphionema montanum*	0.07	0.00
STYLIDIACEAE		
Stylidium productum	0.52	0.00
RUTACEAE		
Boronia pinnata	0.07	0.08

Species recorded at only one site are omitted

+ Species noted by Beadle *et al.* (1982), or known to have a relatively high moisture requirement

Species nomenclature follows updated *Plants of New South Wales* (Jacobs & Pickard 1981)

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Aspects of the ecology of the rare *Grevillea kennedyana* (Proteaceae) in north-western New South Wales

Ann Duncan

Abstract

Duncan, A. (c/- National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, NSW, Australia, 2000) 1992. Aspects of the ecology of the rare Grevillea kennedyana *(Proteaceae) in north-western New South Wales.* Cunninghamia *2(4) 533–539. Grevillea kennedyana* occurs only in Sturt National Park and on adjacent pastoral properties in north-western New South Wales. The number of plants is estimated to be approximately 7 000. Population size and distribution of *Grevillea kennedyana* at Sturt National Park and adjoining properties in the north-western region indicate that the species does not appear to be threatened. Some survival mechanisms of this species are described.

Introduction

Grevillea kennedyana F. Muell. (family Proteaceae) is a shrub of restricted distribution occurring naturally in the extreme north-west of New South Wales. Conservation code is 2VCi, i.e. vulnerable with a range less than 100 km and inadequately reserved (Briggs & Leigh 1988). 'This species is not closely related to any other eastern Australian *Grevillea* species but does have some affinity with *Grevillea juniperina* R. Br. and *G. victoriae* F. Muell. However, it differs from these most significantly in its very oblique torus and its longer ovarian stipe as well as its lack of stylar indumentum, among other things. It shares most features with and appears closely related to *Grevillea acuaria* F. Muell., a Western Australian species,' (P. Olde, pers. comm.).

Prior to this study, populations of *Grevillea kennedyana* were known from mesa slopes at Mount Wood and Olive Downs in Sturt National Park (latitude 29°00' – 29°45' S, longitude 141°40' – 142°05' E) and at the nearby pastoral properties of Onepah to the east and Yandama to the south. The scree slopes of these mesas consist of extensive remnants of a formerly extensive duricrust of silcrete that weathers to moderately coarse fragments overlying brown, loamy lithosols (Geological Survey of New South Wales 1967).

Vegetation is semi-arid low woodland dominated by *Acacia aneura, A. cambagei* and *Atalaya hemiglauca,* with occasional *Casuarina pauper* up to seven metres high. The associated low shrubs include *Eremophila freelingii* (predominant upslope); other species are *Acacia tetragonophylla, Scaevola spinescens,* and species of *Eremophila* and *Senna.* A low chenopodiaceous ground cover is invariably present.

Following the discovery of a third population in Sturt National Park, at McDonalds Peak, an assessment of population size and ecology of *Grevillea kennedyana* was commenced.

Methods

Separate populations of *Grevillea kennedyana* at Mount Wood, Mount Wood Hills, McDonalds Peak, Olive Downs Escarpment and Onepah (Fig. 1) were either counted or estimated. Site differences of aspect, slope, and canopy cover at Mount Wood and at Trig Hill within the Mount Wood Hills were examined. The population age structure, stem size and number, height and canopy cover were recorded on three 100 m^2 study sites at Mount Wood.

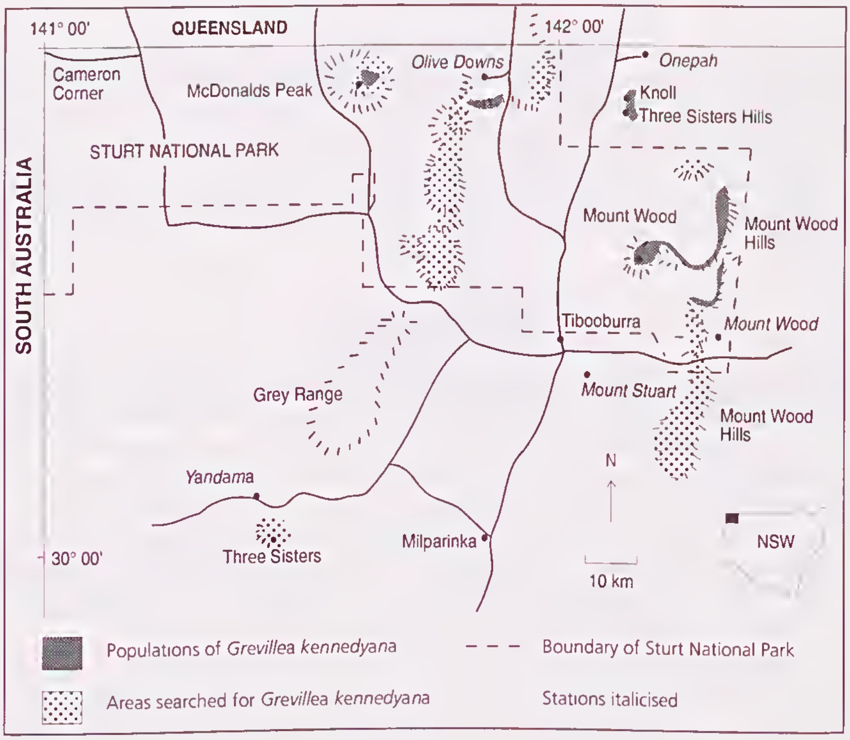


Figure 1. Locations of *Grevillea kennedyana* in north-western New South Wales

Rainfall data were obtained from the Bureau of Meteorology and unpublished records at Tibooburra. Observations on fire regime and pattern were provided by Mr R. Betts, a local resident.

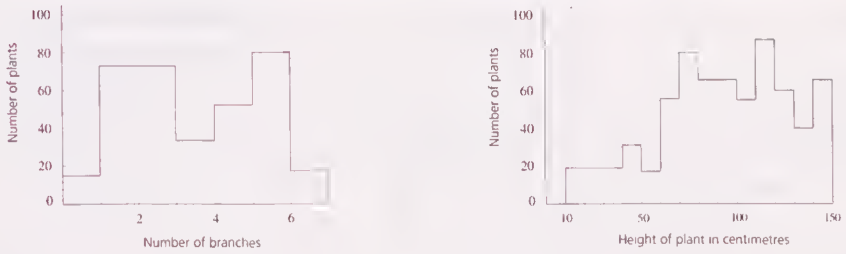
Growth pattern

Grevillea kennedyana is a many-branched shrub arising from either ground level or a consolidated stump (Fig. 2a). Few plants possess more than six thick stems and the majority of these branches are between 4 cm and 8 cm in circumference (Fig. 2b). Overall shrub height is between 0.7 m and 1.5 m, (Fig 2c). An occasional 2 m plant has been observed.

A distinctive feature of *Grevillea kennedyana* populations is the close grouping of plants. Such groups consist of 4 to 8 close growing plants with intertwining branches. Canopies of isolated individual plants average 1.5 m^2, but a group or colony can result in

Figure 2a Number of branches on the plants

2c Height of plants



2b Stem sizes

2d Canopy width

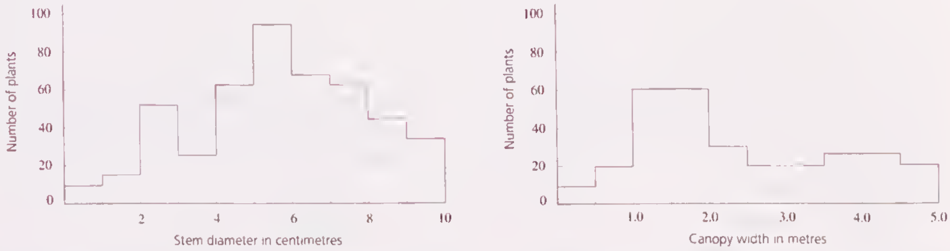


Figure 2. Number of branches, height, stem size and canopy width of *Grevillea kennedyana* plants at Mount Wood

a combined canopy of 3–5 m^2 (Fig. 2d). Formation of most groups appears to be coppicing from roots. This phenomena was most pronounced at Onepah where investigations indicated that the individuals forming a colony had connecting horizontal roots. Other groups may have resulted from seedling establishment near an adult plant.

Distribution and population size

Population counts took these groups into consideration by treating them as one individual. Large populations, ≥ 100, were estimated by counting the number of isolated individual plants and canopies. In smaller populations where plants could be studied individually, difficulties were sometimes experienced in distinguishing between seed-generated and coppicing stands, as this was impossible to confirm without digging up individual plants. Overall total population numbers may be underestimated.

Grevillea kennedyana locations in north-west New South Wales are shown in Fig 1. Its range is only 70 km. The estimated number of plants is now about 7 000 (Table 1). Localised populations of the species are fragmented and discontinuous, with major concentrations at Mount Wood, McDonalds Peak, and East Olive Downs Escarpment. Limited exploration at Yandama failed to locate the previously recorded population, (*Collier*, 1960 NSW 93160).

Altitude range for *Grevillea kennedyana* is from 140 m at Mount Wood to 200 m at Olive Downs. A horizontal concentration of plants midslope is frequently apparent, with an upslope limit about 20 m below ridge crest. Slope ranges from almost level (about 10°) to steep (about 75°) and aspect through 360°.

Table 1. Population numbers of *Grevillea beadleana*

Locality	Total No.	Population range of localised groups
Mount Wood	1 500	30 – 400
Mount Wood Area	650	1 – 200
Mount Wood Hills	> 1 500	1 – 250
McDonalds Peak	900	1 – 100
Olive Downs Escarpment	1 600	47 – 400
Onepah	750	10 – 300
Yandama	–	
Total number	6 900	–

Table 2. Canopy Cover

Mount Wood (29°20'S, 142°10'E)		Trig Hill (29°28'S, 142°11'E)	
Tall shrubs	4%	Tall shrubs	55%
Medium shrubs	6%	Medium shrubs	30%
Grevillea kennedyana	30%		
Low chenopods	60%	Low chenopods	15%
Aspect	0–360°		0–360°
slope	30–45°		45°
Surface	covering of large silcrete rocks		covering of large silcrete rocks

Concentrations of *Grevillea kennedyana* occur where there is little or no other canopy cover and a sparse, low, chenopodiaceous cover between plants of *Grevillea kennedyana* (Table 2). Smaller populations are usually in clearings where trees and taller shrubs are absent. At Mount Wood where the shrub canopy cover is only 10%, *Grevillea kennedyana* cover is 30%. However, at Trig Hill, Mount Wood Hills, where *Grevillea kennedyana* is not present, the shrub canopy cover is 85%. Both Mount Wood and Trig Hill are designated Flat Top (land system series Sheet 54–7). The absence of *Grevillea kennedyana* plants from Trig Hill suggests that this high proportion of canopy cover may be a factor in habitat selection.

The region has low rainfall, 236 mm per year, with a peak in January when isolated summer storms are experienced (Figure 3). There are long periods without precipitation, but the rain that falls in summer is sometimes torrential, so that infrequent though these episodes are, the relative importance of running water as an agent to disperse seeds may be high. Although most larger populations are found on slopes, the frequently observed occurrence of smaller populations of *Grevillea kennedyana* along streams or drainage lines may reflect seed movement by water.

The main Grey Range is similar geologically to McDonalds Peak and Olive Downs escarpment – Tertiary sediment (*Geological Survey of NSW* 1967) – but the absence of *Grevillea kennedyana* from large sections of the Range is not explained (Figure 1). On the slopes of the main Range the underlying erodible material is exposed without a covering of larger rocks, indicating a possible correlation between the nature of the scree slope and the species occurrence. *Grevillea kennedyana* appears to be associated more frequently with slopes containing a higher proportion of rough silcrete scree.

Ecology and management of *Grevillea kennedyana*

The ecology of *Grevillea kennedyana* involves episodes of drought and fire. Life expectancy of mature shrubs is unknown. Although branches greater than 12 cm in circumference are rarely seen, stems up to 20 cm have been observed. Generally, there is very little evidence of plant senescence. Though many *Grevillea* species are short-lived, some are long-lived. An individual of the tree species, *Grevillea striata*, a dense-wooded tree, at Poole's grave near Milparinka, just south-west of Sturt National Park, marked by Sturt in 1845, is still surviving nearly 150 years later.

Flowering occurs during winter and spring, becoming sporadic during drought. The pollinators are unknown, but flower size, red flowers and long styles suggest that it is likely to be bird-pollinated. *Grevillea kennedyana* does not appear to retain fruit or seed in the canopy for long periods after maturation. No fruits were observed during this survey. Regeneration is by seed or vegetatively. Maconochie (1982) suggests that on clay soils regeneration of many arid zone plant species is from seed, either stored in the ground or freshly fallen, and only occurs at irregular intervals under favourable conditions. Populations of *Grevillea kennedyana* consist of mixed size stands which probably relate to different ages. The most recent recruitment from seed would possibly have been after reasonable rain in 1988–89. Other years of regeneration could have been 1984, 1974–76. Resprouting or coppicing, the alternative regenerative method, may enable established individuals to survive and expand under stressed conditions. Observations indicate that *Grevillea kennedyana*, though it does not possess obvious storage organs, has the ability to resprout from adventitious buds in stems (branches), bases and roots. The ability to produce these buds has been observed in many desert plants (Kasses 1966). Stimulation of new growth can be caused by physical damage. Exposure and damage of roots and branches may be caused by macropods as *Grevillea kennedyana* clumps are favoured as rest pads.

The evolutionary significance of fire for Australian arid zone species is not adequately understood. The frequency, intensity and season of fires has radically altered in the last 100–150 years. Overgrazing by domesticated and feral animals, with increased grazing by macropods within the park, together with the predominance of *Atriplex vesicaria*, a species of low flammability (Hodgkinson 1982), has greatly reduced the

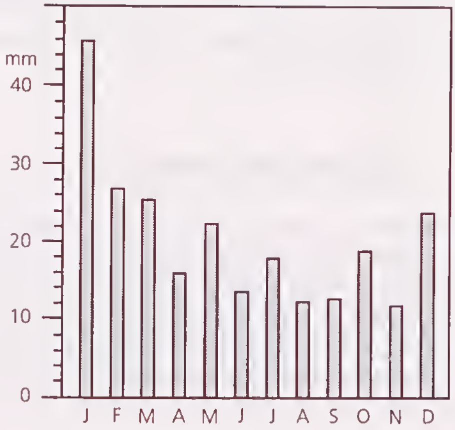


Figure 3. Average monthly rainfall (mm) for Tibooburra 1962—1991

frequency of fire. Since 1975 there have been no fires in the study areas (Mr R. Betts, pers. comm.).

The browsing pattern by animals may also have changed. In general, there is very little evidence of browsing on mature plants. Prior to 1973 all areas would have been grazed by sheep, which prefer chenopodiaceous species (Davey 1983). Since the formation of Sturt National Park and the subsequent removal of livestock, the numbers of Red Kangaroos *(Macropus rufus)* and the Euro *(M. robustus)* have increased. The major component of their diet is grass but in times of drought the Red Kangaroo has been recorded consuming sharp-spined *Sclerolaena* species (Davey 1983), so under severe drought conditions it is possible that *Grevillea kennedyana* may be browsed.

On the pastoral property of Onepah 30–40 plants of *Grevillea kennedyana* 10–12 cm high had numerous densely leaved shoots sprouting from single 1 cm diameter stems. A possible explanation is vegetative recovery after heavy browsing. Kangaroos and rabbits are present on the property but the main browsers are stock. Prior to 1989 sheep were the main animals but they have now been replaced by cattle. Similar reshooting plants were not observed within Sturt National Park.

The rabbit populations were drastically reduced subsequent to the 1950s and the introduction of myxomatosis, but numbers are again increasing. Rabbits are versatile feeders and the impact on regeneration of *Grevillea kennedyana* is unknown. Studies on *Acacia carnei* at Kinchega National Park demonstrated that rabbits graze not only on suckers or seedlings, but also chew roots (Benson 1991). To test the relative importance of rabbit and kangaroo grazing on the survival of young plants, wire cages would need to be erected to exclude either or both these animals. Although goats are a problem elsewhere in western New South Wales, currently they do not constitute a problem in Sturt National Park.

At present the population of *Grevillea kennedyana* does not appear to be threatened in the short term. The disjunct nature of the habitats tends to protect the species even though a local population catastrophe may occur. The majority of the populations are contained within Sturt National Park and are subject to strict conservation practice. With two mechanisms of regeneration, seed and vegetative reproduction, the species may cope adequately with the two major environmental influences of fire and drought. Plants appear to have the potential to live for decades. The absence of young seedlings suggests a possible long-term threat and the monitoring of study areas would indicate whether this is due to animal herbivory or seasonal conditions. Approximately 90% of the population of *Grevillea kennedyana* (over 6 000 plants) is in Sturt National Park and it would therefore appear appropriate to consider revising the conservation status from 2VCi (Briggs & Leigh) to 2VCa.

Acknowledgements

The field work for this study was carried out in Sturt National Park and I wish to thank Paul Jennings, Supervisor at Tibooburra, whose own astute observations in locating the McDonald Peak population prompted this paper, and his colleagues for their continued support. I also greatly appreciate the ecological suggestions by Doug Benson, comments on the manuscript by Bob Makinson, talks with *Grevillea* author Peter Olde, local pastoralist Ross Betts for fire records, Kevin Smith at Tibooburra for rainfall data and Lyn McDougall for drawing the figures and typing the manuscript.

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The natural vegetation of the Penrith 1:100 000 map sheet

D.H. Benson

Abstract

Benson, D.H. (National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, New South Wales, Australia 2000) 1992. The natural vegetation of the Penrith 1:100 000 map sheet. Cunninghamia *2(4) 541–596.* The composition and extent of the present natural vegetation on the Penrith 1:100 000 map sheet 9030 (lat. 33° 30' – 34° 00' S, long. 150° 30' – 151° 00' E) is mapped and described in terms of structure and characteristic species. Eighteen plant communities are recognised including tall open-forests, open-forests, woodlands and sedgelands. Vegetation patterns relate strongly to underlying geology with major groups of communities being restricted to either Wianamatta Shale, Tertiary alluvium, Holocene (Recent) alluvium or Hawkesbury Sandstone. Within these groups, patterns relate to rainfall gradients and soil drainage conditions. Comments are made on the adequacy of the major conservation reserves and botanically significant species are indicated. Conservation issues relate to different land uses on major geological types. Western Sydney's Cumberland Plain makes up the major part of the Penrith sheet; because of the suitability of its soils and terrain for agriculture and suburban development, very little of its vegetation remains and very little of this is conserved. Of 84 species regarded as having particular conservation significance in western Sydney, 44% were recorded in Cumberland Plain Woodlands and 36% in River-flat Forests (including freshwater wetlands), highlighting the need for better conservation of remnants of these vegetation types.

Introduction

'One immense tract of forest land extends, with little interruption, from below Windsor, on the Hawkesbury, to Appin a distance of 50 miles', wrote James Atkinson in 1826. Since then, this forest land has virtually disappeared, replaced by farms, factories and suburban estates. One hundred and sixty years later the few remnants of forest remaining still lack adequate long-term protection.

As part of the Sydney Region Vegetation Map Series, this paper describes the vegetation of the Penrith 1:100 000 map sheet area and, in particular, draws attention to how little remains of the vegetation of western Sydney.

Location, physiography and climate

The Penrith 1:100 000 Vegetation Sheet (based on the Penrith 1:100 000 Topographic Sheet 9030, AUSLIG, Canberra) is bounded by latitudes 33°30' and 34°00' S, and by longitudes 150°30' and 152°00' E. It covers the western region of Sydney extending from Parramatta westward to Springwood on the lower Blue Mountains, and from Kurrajong in the north to Bringelly in the south. This includes the central basin of the Cumberland Plain, which lies between Parramatta and the Blue Mountains, and extends from Richmond in the north to Picton in the south (Figure 1). This is gently

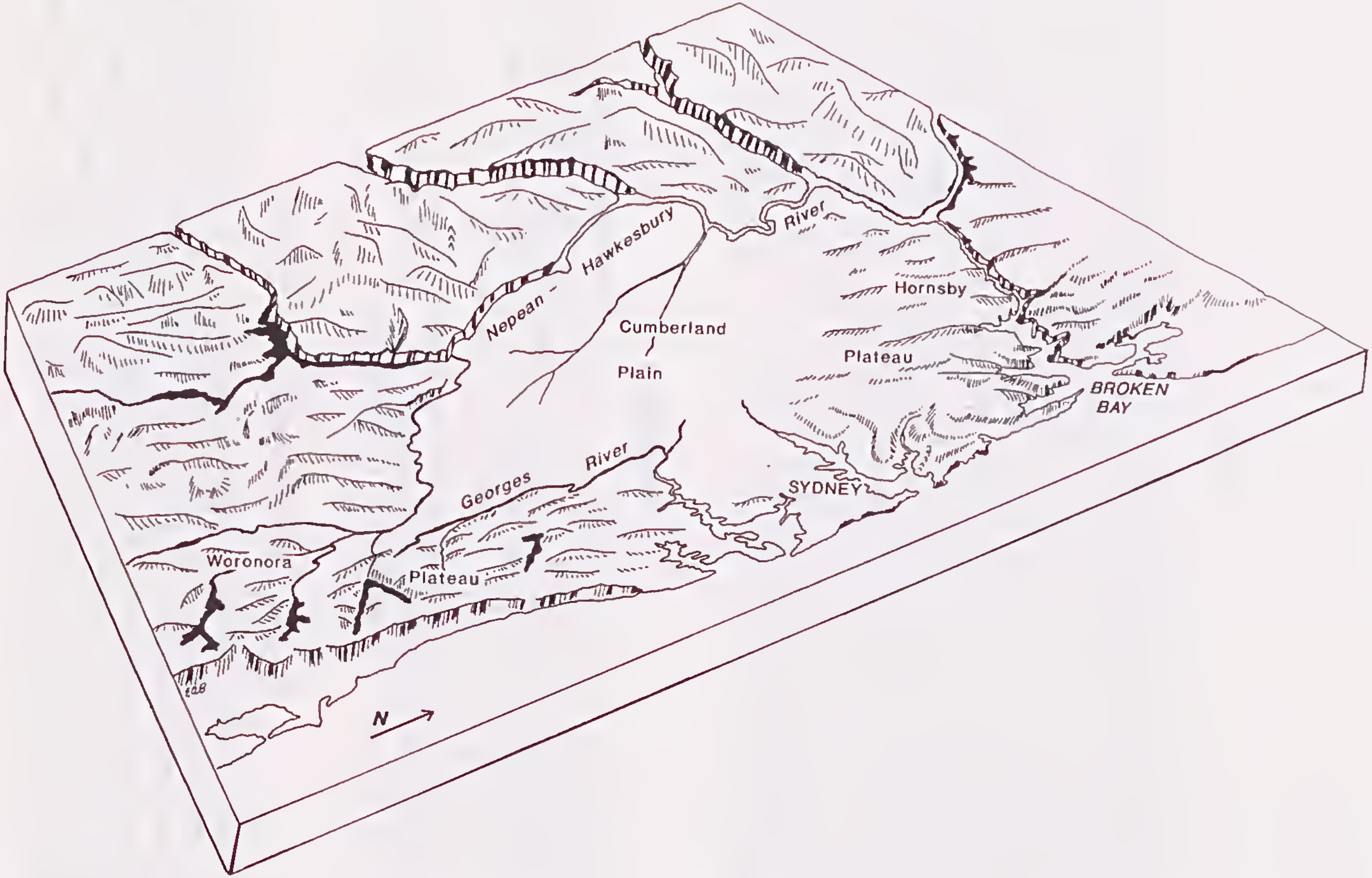


Figure 1. Block diagram of Sydney showing topography of the Penrith sheet area centred on the Cumberland Plain.

undulating to hilly country (altitude generally ranging from 20-100 m a.s.1.), on Triassic Wianamatta Group shale (New South Wales Department of Mines, 1966) and contrasts with the rugged Hawkesbury Sandstone of the lower Blue Mountains and coastal Sydney area.

The Cumberland Plain is bounded on the north and west by the Hawkesbury–Nepean River. Along this river and associated creeks (South Creek, Rickabys Creek, Eastern Creek), and the Georges River, are extensive alluvial deposits of Holocene (Recent) geological age. The largest deposits are on the floodplain of the Hawkesbury River, between Penrith and Windsor, and along the Nepean River near Camden. The fertile agricultural soils formed from these deposits were eagerly sought by the early European settlers who established farms near Windsor in the 1790s. As a result most of these areas are now completely cleared of native vegetation and indeed had probably been cleared by the 1830s.

Between Penrith and Windsor are older alluvial deposits of gravel, sand, silt and clay of mainly Tertiary age, deposited by an ancestral Hawkesbury–Nepean river system (Gobert 1978). Many of these deposits still retain their original natural vegetation though this is being destroyed by extensive sand, gravel and clay extraction and piecemeal suburban expansion.

Along the western edge of the Cumberland Plain, the lower Blue Mountains rise from about 200 m a.s.1. along the Lapstone Monocline at Glenbrook to 500 m at the western margin of the map sheet. They form a dissected plateau of Hawkesbury Sandstone of Triassic age but stratigraphically lower than the Wianamatta Shale which covers the downwarped Cumberland Plain. Remnant Wianamatta Shale cappings persist along the sandstone ridges followed by the Great Western Highway as far west as Faulconbridge and as far as Mt Tomah on the ridge followed by Bells Line of Road. Hawkesbury Sandstone borders the northern edge of the Cumberland Plain and occurs extensively between Annangrove and Cattai in the north-eastern corner of the Penrith Sheet and near the Georges River in the south-east corner. Many areas of Hawkesbury Sandstone still carry relatively undisturbed natural vegetation.

A number of volcanic outcrops (mostly diatremes) occur on the sheet area, though most have been cleared of native vegetation including the largest, at Prospect. Smaller uncleared outcrops are found in the Blue Mountains.

Soil landscapes of the Penrith sheet (Bannerman & Hazelton 1990) relate strongly to geology and can generally be associated with characteristic natural vegetation. Soils derived from Hawkesbury Sandstone are strongly acid. They are characteristically deficient in phosphate and are often locally deficient in nitrogen. Soils from the Wianamatta Group are strongly acid and intrinsically deficient in phosphorus, nitrogen and calcium.

Average annual rainfall on the Cumberland Plain is low. It is highest on the eastern edge (Parramatta 911 mm p.a.) and decreases westward (St Marys 759 mm, Windsor 757 mm, Bringelly 760 mm p.a.), increasing again with the rising elevation of the Blue Mountains (Faulconbridge 1 150 mm, Bilpin 1 300 mm p.a.). Mean maximum temperatures for January are 28–29°C for most of the sheet (e.g. Parramatta 28.1°C). The highest maximum temperature recorded for Parramatta is 46.3°C. Mean temperatures for July are highest on the eastern side (Parramatta 4.5°C) and decrease westward (Richmond 3.6°C). Frosts are common on the Cumberland Plain and the lowest minimum temperature for Richmond is -8.3°C. (Figures from Bureau of Meteorology, 1979).

In terms of regional rainfall the Penrith map sheet area is almost wholly within Zone 3 of Edwards' (1979) rainfall zones which extends to the northwest of New South

Wales. Stations within this zone have median annual rainfall of 440–810 mm and a tendency for a higher proportion of that annual total to occur in the warmer months of the year. In the Penrith area, as well as being greater, the summer rainfall is less variable than the winter rainfall (Figure 2).

Soil moisture availability in this zone is relatively high throughout the year reaching a peak in winter when the lower rainfall is more than compensated for by the low evaporation. Plant growth is limited by low temperatures during winter and by low soil moisture at other times.

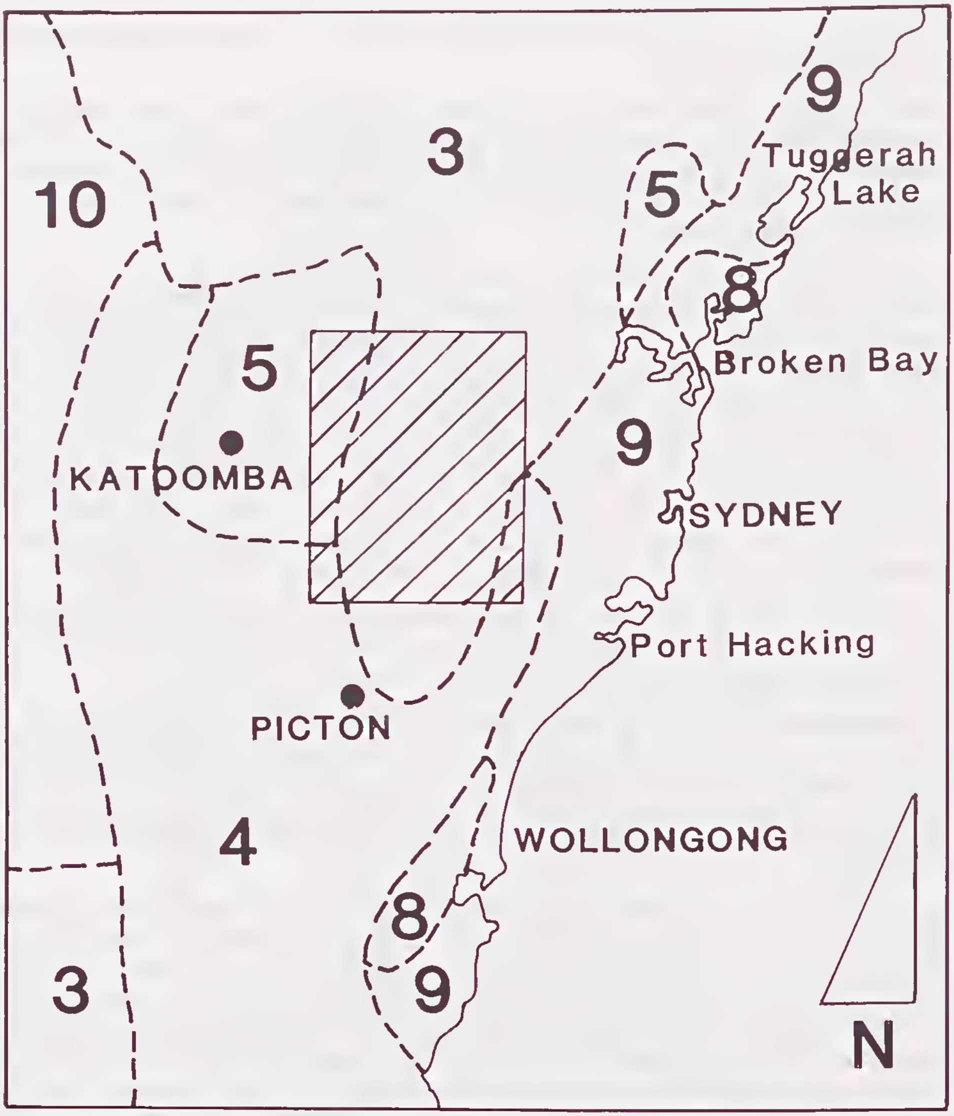


Figure 2. Location of Penrith map sheet area showing rainfall zones of Edwards (1979). Stations within zone 3 have median annual rainfalls of 440-810 mm with a higher proportion occurring in the warmer months. Adjoining zones 4, 5 and 9 receive higher rainfall.

Methods

Areas of vegetation with similar structure (Specht 1970) and floristics (dominant species) were grouped to form the map units on the basis of aerial photopatterns and recognisable geological and landscape characteristics. Black-and-white aerial photography from the New South Wales Department of Lands (Penrith 1:40 000 scale taken in September 1979) was used initially and updated with late–1988 and early–1989 photography. Compilation maps were prepared at 1:25 000 scale and subsequently reduced to 1:100 000 scale.

Present-day (i.e. 1989) vegetation is mapped, but comments on the original natural vegetation of some agricultural and urban areas are also provided. An alphanumeric code is used to distinguish individual plant communities. The numeric code represents the structural form of the plant community and the alphabetic code represents the characteristic species. The codes used are consistent throughout the Sydney Region 1:100 000 Vegetation Map Series, allowing map units to be cross-referenced (Benson 1986, Keith & Benson 1988, Benson & Keith 1990).

There are a number of constraints in reducing the complex pattern of natural vegetation to a map format. The map units recognised are not all of equivalent rank. Some are essentially land units made up of several plant communities associated with a particular geological or physiographic type (e.g. map units 28a) whereas others are more clearly plant associations (*sensu* Beadle & Costin, 1952) (eg. map units 10c, 14a). Generally the term 'plant community' is used for the basic vegetation unit. Map units have also been provided with common names based loosely on habitat and composition, for ease of reference.

The vegetation map is a diagrammatic attempt to simplify the distribution patterns of an often rich and varied flora, over an extensive region. It is scale-dependent and map units will almost invariably include unmapped areas of other map units too small to be shown separately. Similarly, most plant communities do not have clear-cut boundaries but grade into each other, often over a broad ecotone. For mapping purposes such boundaries have to be represented by a line.

Field checking has been carried out intermittently between 1975 and 1990, and included notes on structure, characteristic species of major strata and associated environmental factors. Extensive species lists were compiled for particular areas. Available species lists are listed in bibliographies such as those of Pickard (1972), Bryant & Benson (1981) and Keith (1988); copies of some of these are available from the Royal Botanic Gardens Library.

Specific sets of data were collected for the Wianamatta Shale and Tertiary alluvium. The Wianamatta Shale data consisted of 100 sites, each 400 m^2 in area, randomly located in Western Sydney, for which species presence had been recorded. Data collection was carried out between 1973–1978. The Tertiary alluvium data was of 30 similarly recorded sites, collected between 1978–1980 on a grid basis. Basal area and plant density data from these sites has been presented for some plant communities. A high frequency of small size classes, for example, probably indicates a period of regeneration following clearing or logging. Such data give an indication of community dynamics as well as providing guidelines for regeneration and planting programs.

Botanical names used are those currently recognised at the National Herbarium of New South Wales. For authorities see Jacobs & Pickard (1981), with alterations in Jacobs & Lapinpuro (1986), or Harden (1990–1991).

Vegetation

The Penrith area was explored within months of the settlement at Port Jackson in 1788 and accounts of the expeditions of Governor Arthur Phillip, John Hunter and Watkin Tench exploring the Nepean–Hawkesbury River include descriptions of the landscape and its general vegetation (see Benson & Howell 1990*a*). References to the occurrences of particular species occur in the writings of George Caley (Currey 1966) and Allan Cunningham (Lee 1925). The strong correlations between the type of vegetation and the potential agricultural value of the land was frequently commented upon. In particular the marked differences between the Hawkesbury Sandstone landscapes and those of the heavier-textured and agriculturally superior soils developed from Wianamatta Shale and alluvium of the floodplains were frequently observed. For example, Allan Cunningham reports in his journal on 23 December 1816, after travelling from Parramatta to Sydney: 'As I advanced on the Road, I observed that the Botany fell off, on some rich pasture lands that I pass'd, and [on] those spots where the Vegetable Kingdom appear'd in greater Luxuriance their exuberance was a certain indication of the Sterility of the Soil.'

Scientific study of the plant communities began with Pidgeon (1937, 1941) who described general differences in vegetation on Wianamatta Shale and Hawkesbury Sandstone in the Sydney Region. Phillips (1947) described the main plant communities of western Sydney and Forster *et al.* (1977) included descriptions based on early work by the present author though neither work included detailed mapping. The distribution of the original vegetation of the floodplain of the Nepean-Hawkesbury River has been mapped (Benson 1974). A recent account of the vegetation of the Sydney area, defined by the County of Cumberland, describes and maps eight major vegetation types (Benson & Howell 1990*a*). A modified section of that map showing the extent of natural vegetation in 1788 for the Penrith map area is given in Figure 3. As this map sheet deals with about half of the area covered by Benson & Howell, the relationship between those vegetation types and the map units described here is given in Table 1.

Table 1. Vegetation types of Benson & Howell (1990*a*) (in bold) with corresponding map units and codes.

Turpentine - Ironbark Forest	Turpentine - Ironbark Forest	9o
Cumberland Plain Woodlands	Spotted Gum Forest	9b
	Shale/gravel Transition Forest	9d
	Grey Box Woodland	10c
	Grey Box - Ironbark Woodland	10d
Castlereagh Woodlands	Shale/gravel Transition Forest	9d
	Castlereagh Ironbark Forest	9e
	Castlereagh Scribbly Gum Woodland	14a
	Agnes Banks Woodland	14b
	Swamp Woodland	14c
River-flat Forests	Camden White Gum Forest	6d
	River-flat Forest	9f
Sandstone heaths, woodlands & forests	Sydney Sandstone Gully Forest	10ag
	Sydney Sandstone Ridgetop Woodland	10ar
	Lower Blue Mountains Heath (part)	21f
Freshwater and Estuarine wetlands	Estuarine Complex	4a
	Freshwater Reed Swamps (floodplain wetlands only)	28a

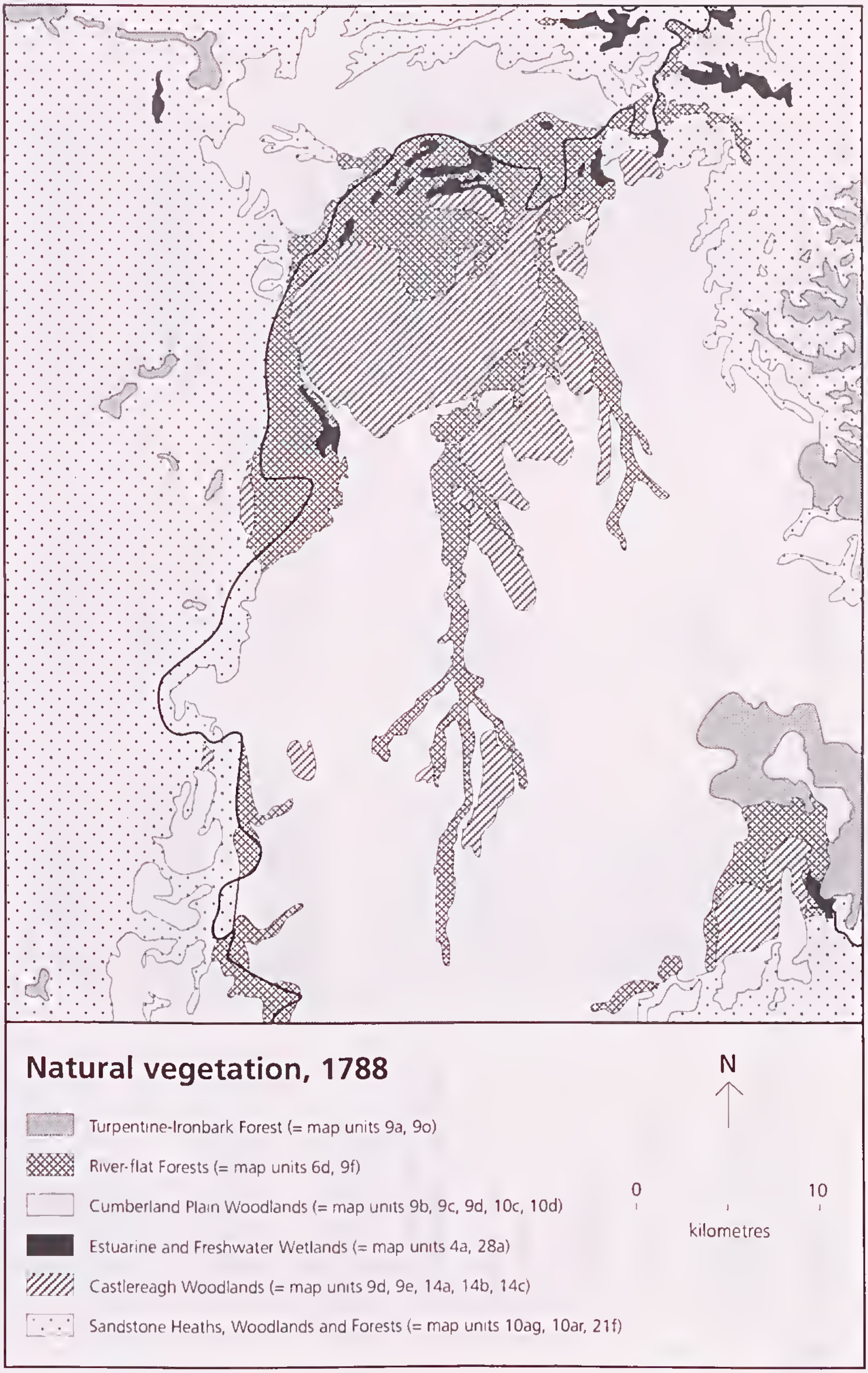

Natural vegetation, 1788
Turpentine-Ironbark Forest (= map units 9a, 9o)
River-flat Forests (= map units 6d, 9f)
Cumberland Plain Woodlands (= map units 9b, 9c, 9d, 10c, 10d)
Estuarine and Freshwater Wetlands (= map units 4a, 28a)
Castlereagh Woodlands (= map units 9d, 9e, 14a, 14b, 14c)
Sandstone Heaths, Woodlands and Forests (= map units 10ag, 10ar, 21f)
N
0
10
kilometres

Figure 3. Presumed 1788 or pre-European pattern of natural vegetation of the Penrith map sheet area.

Table 2. Map unit, common name, structure, main canopy species, geology and occurrence of plant communities in the area covered by the Penrith 1:100 000 map sheet.

Map Unit	Structure	Main canopy species	Geology	Occurrence
4a	**Estuarine Complex**			
	Open-scrub	*Avicennia marina* *Aegiceras corniculatum*	Holocene alluvium	Estuarine mudflats regular tidal inundation
	Rushland / Reedland	*Juncus kraussii* *Phragmites australis*		Infrequent inundation. Brackish water
	Low open-forest Open-scrub	*Casuarina glauca* *Melaleuca ericifolia*		
6c	**Glen Forest**			
	Tall open-forest	*Eucalyptus deanei*	Diatremes	Isolated outcrops in Blue Mountains
6d	**Camden White Gum Forest**			
	Tall open-forest	*Eucalyptus benthamii*	Holocene alluvium	Confined to Nepean River at Bents Basin, Wallacia
9a	**Shale Cap Forest**			
	Open-forest	*Eucalyptus paniculata* *Eucalyptus notabilis*	Wianamatta Shale	Ridges along Bells road
9b	**Spotted Gum Forest**			
	Open-forest	*Eucalyptus maculata* *Eucalyptus moluccana*	Wianamatta Shale	On hills around Hoxton Park. Also around Werombi
9c	**Ironbark Forest**			
	Open-forest	*Eucalyptus crebra* *Eucalyptus fibrosa*	Wianamatta Shale	On shale remnants at Glenbrook
9d	**Shale/Gravel Transition Forest**			
	Open-forest	*Eucalyptus fibrosa* *Eucalyptus moluccana*	Wianamatta Shale/ Tertiary alluvium	On transition zone between these geological units

Map Unit	Structure	Main canopy species	Geology	Occurrence
9e	**Castlereagh Ironbark Forest**			
	Open-forest	*Eucalyptus fibrosa*	Tertiary alluvium	Castlereagh area on clay soils
9f	**River-flat Forest**			
	Open-forest	*Angophora subvelutina* *Eucalyptus amplifolia* *Eucalyptus tereticornis*	Holocene alluvium	Alluvial flood plains along Nepean-Hawkesbury River and major tributary creeks
9o	**Turpentine-Ironbark Forest**			
	Open-forest	*Syncarpia glomulifera* *Eucalyptus paniculata*	Wianamatta Shale	Bankstown area
Sydney Sandstone Complex				
10ag	**Sydney Sandstone Gully Forest**			
	i) Tall open-forest	*Eucalyptus deanei* or *Eucalyptus saligna*	Hawkesbury Sandstone/ Narrabeen Group	Sheltered gullies
		Angophora floribunda		Hillsides
		Syncarpia glomulifera		Sheltered gorges
	ii) Closed-forest	*Ceratopetalum apetalum* *Doryphora sassafras*		
	iii) Open-forest	*Eucalyptus piperita* *Angophora costata* +/- *Eucalyptus pilularis*	Hawkesbury Sandstone	Gullies, sheltered hillsides
10ar	**Sydney Sandstone Ridgetop Woodland**			
	i) Low open-forest	*Eucalyptus sieberi* *Eucalyptus piperita*	Hawkesbury Sandstone	Ridgetops and plateaus >1200 mm pa

Map Unit	Structure	Main canopy species	Geology	Occurrence
10ar	**Sydney Sandstone Ridgetop Woodland (continued)**			
	ii) Woodland / Open woodland	*Eucalyptus gummifera* *Eucalyptus eximia* *Eucalyptus sparsifolia* *Angophora costata* *Angophora bakeri*	Hawkesbury Sandstone	Ridges and dry exposed hillsides
	iii) Open-forest / woodland	*Eucalyptus gummifera* *Angophora costata* *Eucalyptus notabilis* *Eucalyptus sparsifolia* *Eucalyptus punctata* *Syncarpia glomulifera*	Hawkesbury Sandstone with clay influence	Ridges
	iv) Open-scrub	*Angophora hispida*		Broad plateau surfaces
10c	**Grey Box Woodland**			
	Woodland	*Eucalyptus moluccana* *Eucalyptus tereticornis*	Wianamatta Shale	Flat to gently undulating basin of of Cumberland Plain. Clay soils
10d	**Grey Box-Ironbark Woodland**			
	Woodland	*Eucalyptus moluccana* *Eucalyptus tereticornis* *Eucalyptus crebra*	Wianamatta Shale	Undulating to hilly country on margins of Cumberland Plain. Clay soils
14a	**Castlereagh Scribbly Gum Woodland**			
	Low Woodland	*Eucalyptus sclerophylla* *Angophora bakeri*	Tertiary alluvium	Castlereagh-Londonderry and Holsworthy on sandy soils

Map Unit	Structure	Main canopy species	Geology	Occurrence
14b	**Agnes Banks Woodland** Low woodland / open scrub	*Eucalyptus sclerophylla* *Angophora bakeri* *Banksia serrata*	Tertiary alluvium	Confined to sand deposit at Agnes Banks
14c	**Swamp Woodland** Low woodland	*Eucalyptus parramattensis*	Tertiary alluvium	Poorly drained depressions and creek lines
21f	**Lower Blue Mountains Heath** Open-heath	*Eucalyptus stricta* *Allocasuarina nana*	Hawkesbury Sandstone	Dry, rocky ridge tops
26a	**Blue Mountains Sedge Swamps** Closed-sedgeland	*Gymnoschoenus sphaerocephalus* *Lepidosperma limicola* *Xyris ustulata* *Baeckea linifolia*	Hawkesbury Sandstone	Poorly-drained sites on plateaus
28a	**Freshwater Reed Swamps** Open-sedgeland	*Eleocharis sphacelata* *Juncus usitatus* *Persicaria* spp.	Holocene alluvium	Freshwater swamps
C	**Cleared**	These areas are generally the better agricultural soils along the river alluvial flats or on the Wianamatta Shale country. Small remnants of native vegetation too small to show on the map may occur here.		

Description of map units

A summary of the map units recognised on the Penrith sheet, their structural formations, main canopy species, geology and occurrence are given in Table 2. The map unit numbering system applies to the complete Sydney Region Vegetation Map Series. Missing numbers are those used for plant communities that are not found on the Penrith sheet. The vegetation map is located inside the back cover. The current work enlarges upon and updates a previous draft report (Benson 1981) and provisional maps (1981, 1985).

Map unit 4a - Estuarine Complex

Open-scrub:	*Avicennia marina*
Rushland/reedland:	*Juncus kraussii - Phragmites australis*
Low open-forest:	*Casuarina glauca*
Open-scrub:	*Melaleuca ericifolia*

Estuarine vegetation is confined mainly to the saline and brackish estuary of the Georges River downstream from Milperra Bridge. There is a variety of vegetation relating to the degree of flooding and the levels of salinity involved. The margin of the Georges River is fringed with mangroves, with both species that occur near Sydney, *Avicennia marina* and *Aegiceras corniculatum*, represented. They also extend into tributary creeks, in particular Deadmans Creek at Sandy Point and Williams Creek at Voyager Point. These mangroves are restricted to the intertidal zone. *Avicennia* is a ready coloniser of silt deposits, growing rapidly once established from water-dispersed seedlings. Studies in the Lane Cove River (McLoughlin 1985) indicate that *Avicennia* has responded to changes in sedimentation patterns in the river resulting from European settlement. This has generally caused increased silt deposits and in some places mangroves have increased their extent considerably, spreading further into the river. For the Georges River, Mitchell (1988) reports that over the last 50 years there has been a decrease in the area of saltmarsh communities and that generally mangroves have spread inland into saltmarsh areas. Local bank erosion and the loss of mangroves is occurring in some places possibly as a result of power boat wave damage (Ted Trainer pers. comm.).

Extensive saltmarsh with *Sarcocornia quinqueflora*, characteristic of saltmarsh further down the estuary and in particular at Towra Point, does not occur upstream of Mill Creek, probably because of different salinity or flooding frequencies. However, near the mouth of Williams Creek, behind the mangrove margin, is an estuarine sedgeland of *Juncus kraussii*, *Baumea juncea* and *Phragmites australis* and a number of saltmarsh species such as *Samolus repens*. An interesting record here is of *Wilsonia backhousei*, a rare saltmarsh plant previously known in the Sydney area only from Homebush Bay on the Parramatta River. This area would receive periodic brackish flooding.

Boundary relationships between mangroves and saltmarsh in the Georges River have been studied by Mitchell (1988). Boundary elevations of mangrove and saltmarsh decrease with distance from Botany Bay. These decreases appear to be more strongly related to river salinities than to tidal influences. Because of their decreased elevation and the increased tidal range further upstream, saltmarsh communities are tidally inundated more frequently up-river than in Botany Bay. Mitchell (1988) estimates that mangroves along the Georges River are tidally flooded between 17 and 60 times per month and saltmarsh 0 to 26 times.

Thickets or dense scrub of *Melaleuca ericifolia* 2–3 m high with some *Melaleuca linariifolia* and *Kunzea ambigua* (these last two species are normally asociated with non-brackish sites) occurs on sites with perhaps less saline influence but low lying and subject to occasional flooding. There is an extensive area of this scrub at Hammondville and it appears to have been common on the Milperra side of the Georges River in Kelso Park, though these areas have now been destroyed. Scrub in Deepwater Park is related but has less saline influence.

Zones of *Casuarina glauca* forest occur behind the mangroves along the Georges River and along Williams Creek. Low open-forest of *Casuarina glauca* is characteristic of estuaries but also occurs away from the coast in non-estuarine sites where there is some saline influence (for example in the Hunter Valley and on the Cumberland Plain). *Casuarina glauca* occurs between Liverpool and Camden, and south of Penrith where it is probably influenced by the salinity of the Wianamatta Shale groundwater (Figure 4). It occurs, for example, along creeks draining from shale areas such as Lansdowne Creek and Cabramatta Creek.

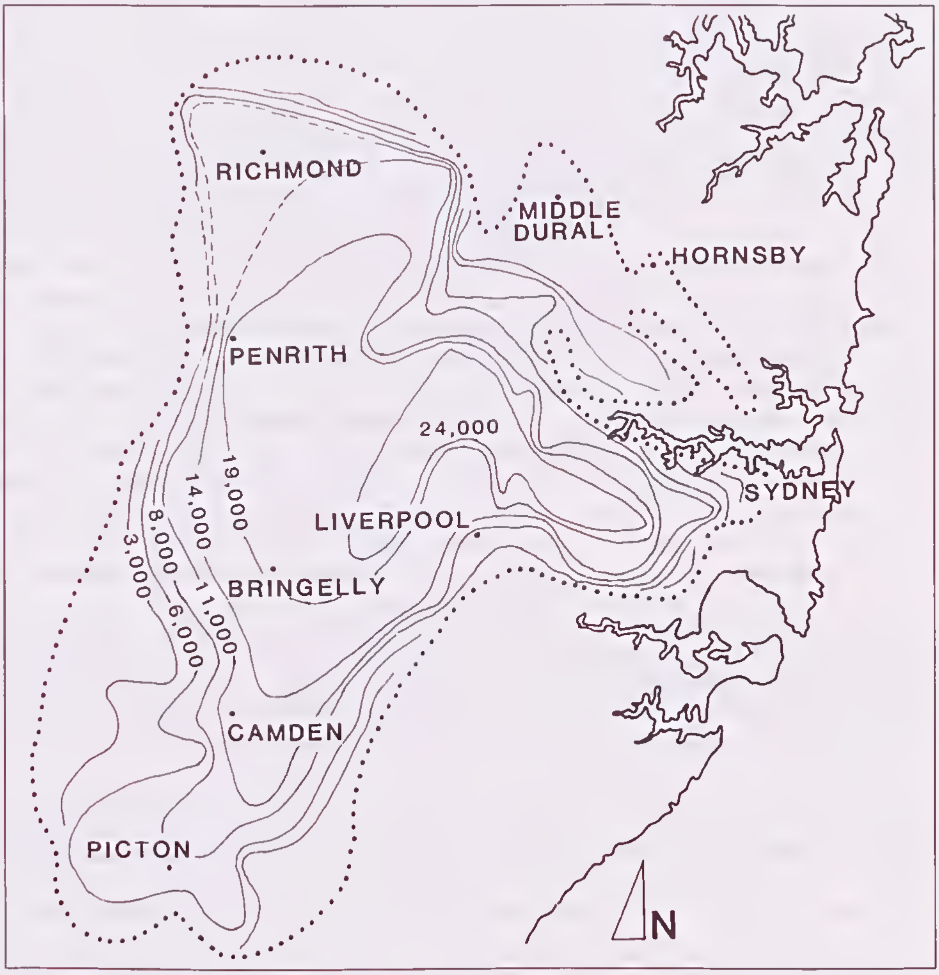


Figure 4. Soil salinity contours (ppm) for Wianamatta Shale groundwater (from Old 1942).

Swamp Oak Forest would have graded into the 'River Flat Forests' on the better drained alluvial flats and the 'Grey Box Woodlands' on nearby Wianamatta Shale hills. A stand of *Casuarina glauca* representing the intergrading form of the community is included within a proposed Nature Reserve at Kemps Creek.

Adam & Stricker (1989) report about 65 ha of estuarine wetland occurs along the Georges River in the Liverpool 1:25 000 map sheet area, with high naturalness ratings for Deadmans Creek, Williams Creek and Lieutenant Cantello Reserve.

Map unit 6c - Glen Forest

Tall open-forest: *Eucalyptus deanei*

In the lower Blue Mountains there are a number of small amphitheatre-shaped valleys formed from eroded volcanic intrusions or diatremes. Diatreme soils are variable, derived from the mixing of sandstone and basalt or breccia substrate as a result of the collapse of the sandstone wall-rocks into the volcanic intrusion and the subsequent deposition of sand eroded from the surrounding sandstone ridges (Crawford *et al.* 1980). They may have a sandy loam overlying a hardsetting clay loam forming red or yellow podzolic soils of the Volcanic Soil Landscape (Bannerman & Hazelton 1990). Such sites are more fertile than the surrounding Hawkesbury Sandstone countryside and have distinctive vegetation. This may be tall open-forest with trees of *Eucalyptus deanei* and *Syncarpia glomulifera*, an understorey with tall shrubs of *Notelaea longifolia, Acacia obtusifolia, Pultenaea flexilis, Hakea dactyloides* and *Polyscias sambucifolia*, climbers including *Smilax australis, Tylophora barbata, Eustrephus latifolius, Cissus hypoglauca, Hibbertia dentata, Clematis aristata* and *Comesperma volubile*, and ground cover dominated by *Calochlaena dubia, Dianella caerulea, Lomandra longifolia* and *Pteridium esculentum*, as at Murphys Glen on the adjacent Katoomba Sheet (Keith & Benson, 1988). On drier aspects there may be ironbarks, *Eucalyptus beyeriana* with a predominantly grassy understorey as at Machins Crater or on the Jack Evans Track near Erskine Creek. However, these diatremes often provided the best, though very localised, agricultural sites and were sought out and cleared or grazed by the early settlers. Tobys Glen and St Helena were grazed before becoming National Park. The ground cover is now dominated by ferns, particularly *Calochlaena dubia* and *Pteridium esculentum* and scramblers such as *Smilax* and *Cissus*, indicating a similar floristic composition to Murphys Glen, before stock grazing. St. Helena had 'well grassed forest land' at the turn of the century (Carne 1908). Where the soil fertility is lower, perhaps derived more from the surrounding rock than from volcanic breccia basalt, other species may occur. The Valley at Valley Heights, now mainly cleared, has remnant trees of *Eucalyptus amplifolia* and appears to have had a more grassy understorey. In William Cox's Journal of Road Construction over the Blue Mountains in 1814, mention is made of feeding and watering stock in the Valley, 'Nine and a half miles [from Emu Plains] grass and water in valley to right of road about a quarter of a mile' (quoted in Carne 1908). This indicates the importance of these grassy *oases* to the early settlers struggling through the poor sandstone country.

Small diatremes are also scattered across the Wianamatta Shale of the Cumberland Plain to the east (Crawford *et al.* 1980). These have all been cleared, and many quarried for crushed aggregate and there is very little evidence of their original flora, which would have been more like Valley Heights than Murphy Glen because of the lower rainfall and the clay influences from the surrounding Wianamatta Shale.

The large volcanic intrusion at Prospect forms a hill rather than an amphitheatre, but the vegetation here was cleared long before its flora had been recorded. It appears to have had *Eucalyptus moluccana* woodland similar to that of the surrounding Wianamatta Shale country (Phillips 1947). A number of uncommon ground species including *Ranunculus sessiliflorus, Scutellaria humilis* and possibly *Pultenaea microphylla* may be indicative of volcanic influence (Benson 1989). *Eucalyptus moluccana* is a common species on diatremes in the Putty area north of Windsor (Barwick 1903).

Map unit 6d - Camden White Gum Forest

Tall open-forest: *Eucalyptus benthamii*

A localised patch of tall open-forest restricted to a sand-bank and adjacent river bank of the Nepean River at Bents Basin, south of Wallacia, is dominated by large trees of *Eucalyptus benthamii*, Camden White Gum, originally up to 40 m in height, but altered by recent fire occurrences. Smaller trees include *Eucalyptus baueriana, E. elata* and *Angophora subvelutina*. The understorey has tall shrubs of *Acacia binervia* and *A. floribunda* with smaller native shrubs such as *Breynia oblongifolia* and *Hymenanthera dentata*. Ground cover is variable with patches of *Lomandra longifolia, Pteridium esculentum*. Introduced weed species, including *Cynodon dactylon, Olea africana, Tradescantia albiflora, Araujia hortorum* and *Ligustrum sinense* are common (Benson, Thomas & Burkitt 1990).

Eucalyptus benthamii is now a rare tree species but formerly occurred along the Nepean River flood-plain as far downstream as the Grose junction and along parts of the Coxs River and Kedumba Creek (Keith & Benson, 1988). Clearing has reduced its occurrence along the Nepean River to scattered trees, and Warragamba Dam has flooded much of its former occurrence in the Coxs valley. It is a long-lived tree (possibly up to 250 years) with periods of recruitment related to flooding and silt deposits, and death related to periods of frequent, or perhaps extreme fire events (Benson 1985). Whilst mature trees are able to recover from fire by suckering, small trees and newly growing suckers are vulnerable.

The occurrence of this relatively fire-sensitive species and the closely-related *E. viminalis* on alluvium along the floodplain of the Nepean may be attributable to particular soil and moisture requirements, but is also consistent with a fire regime, in the nearby Cumberland Plain woodland, of frequent low intensity burns confined to the grassy understorey, that failed to burn the more mesic vine and shrubby understoreys associated with the riverbanks, (such understorey can be inferred from early writers such as John Hunter; (see Benson & Howell 1990*a*), together with an occasional infrequent intense fire event under exceptional fire conditions.

Map unit 9a - Shale Cap Forest

Open-forest: *Eucalyptus notabilis - E. globoidea - Syncarpia glomulifera*

The most western remnants of Wianamatta Shale, reduced to cappings along the sandstone ridges are found along the Bells Line of Road from Kurrajong Heights to beyond Bilpin and near Springwood. Soils here are deep, relatively well drained clays, and originally carried tall open-forest on the wetter sites and open-forest on the drier sites and shallower margins of the shale. The tall open-forest was characterised by *Eucalyptus deanei* and *Syncarpia glomulifera* but has almost all been cleared for orchards and housing. Patches of the open-forest remain. This has tree species such as *Eucalyptus notabilis, E. globoidea, E. paniculata, E. cypellocarpa* and *Syncarpia glomulifera*. Common on the ecotone with the adjoining Hawkesbury Sandstone are *E. punctata* and *E. piperita*. The understorey has shrubs of *Acacia parramattensis* up to 4 m high and lower shrubs, commonly *Indigofera australis, Helichrysum elatum* and *H. diosmifolium*. A conspicuous component of the understorey are vines, *Smilax australis, Tylophora barbata, Kennedia rubicunda, Eustrephus latifolius* and *Glycine* spp. Grasses include *Entolasia marginata, Dichelachne rara, Microlaena stipoides* and *Echinopogon ovatus*, herbs include *Dichondra repens* and *Poranthera microphylla* and ferns, *Pteridium* *esculentum* and *Culcita dubia*. South of Springwood rainfall is lower and isolated shale residuals have the closely related Ironbark Forest, map unit 9c. Map units 9a and 9c are all part of the broadly defined Turpentine-Ironbark Forest of Benson & Howell (1990*a* & *b*).

Map unit 9b - Spotted Gum Forest

Open-forest: *Eucalyptus maculata* - *E. moluccana*

Open-forest of *Eucalyptus maculata*, the easily recognisable Spotted Gum, and *E. moluccana* is found on Wianamatta Shale on hilly country at Hoxton Park and Cecil Park west of Liverpool, and from Werombi southward to The Oaks. There is also an outlier at Appin. Rainfall ranges from 750 to 875 mm p.a. The hilly topography at Hoxton Park and the topographic position of the shale which overlies Hawkesbury Sandstone near Werombi, appears to improve the drainage of the normally damp Wianamatta Shale soils and may explain the occurrence of *Eucalyptus maculata*. A slightly higher rainfall at Werombi (1 000 mm p.a.) may also explain its distribution there.

Eucalyptus maculata made up nearly 60% of the total basal area and over 40% of the total density (Table 3). Usage for timber evidently began very early. A sale notice in the Sydney (Morning) Herald in November 1831 for a farm watered by Orphan School Creek, probably near Edensor Park or Cecil Park advertised 'Timber growing of valuable qualities, one of which (Spotted Gum) is now daily rising in repute for Staves of Casks ...'.

Other tree species are *E. fibrosa*, which occurs sporadically, *E. crebra*, which is particularly important around Werombi, *E. tereticornis* which is frequently important in depressions and *E. quadrangulata* which is found in a few moist, sheltered sites in the Werombi area. Occasional small tree species include *Allocasuarina torulosa*, *A. littoralis*, *Melaleuca decora* and *Acacia implexa*.

At Hoxton Park the understorey is mainly grasses with dense patches of shrubs 2 m high. These patches of shrubs are composed almost entirely of *Bursaria spinosa* (frequency 88% i.e. recorded at 88% of sites) accompanied occasionally by scattered

Table 3. Basal area and density of major tree species from 9 sites in *Eucalyptus maculata* - *E. moluccana* open-forest.

	Basal area (m²/ha)			**Density (plants/ha)**		
	mean	(± s.e.m.)	% of total area	mean	(± s.e.m.)	% of total density
Eucalyptus maculata	14.2	4.1	59	225	97	43
E. moluccana	2.4	1.0	10	67	42	13
E. fibrosa	2.2	1.2	9	42	27	8
Total	24.0	3.1		516	135	

Other species contributing to total basal area - trees *Eucalyptus crebra, E. tereticornis, E. longifolia, E. punctata, E. quadrangulata*; small trees *Allocasuarina torulosa, A. littoralis, Melaleuca styphelioides, M. decora, Acacia implexa, A. parramattensis, Exocarpos cupressiformis*.

shrubs of *Dillwynia juniperina* and *Indigofera australis.* The normally prostrate twiner *Hardenbergia violacea* occurs as a 'shrub form' commonly up to 0.5 m high. Grass species are *Aristida vagans* (frequency 44%), *Entolasia marginata* (55%), *Eragrostis leptostachya* (44%), *Themeda australis* (66%) and *Echinopogon caespitosis* (55%). Common native herb species are *Brunoniella australis* (66%), *Dichondra repens* (77%), *Oxalis corniculata group* (44%), and *Pratia purpurascens* (55%).

At Werombi the understorey is much richer in shrub species, with *Breynia oblongifolia, Persoonia linearis, Allocasuarina torulosa, Acacia implexa* and *Clerodendrum tomentosum.* Twiners, *Geitonoplesium cymosum, Eustrephus latifolius, Stephania japonica* and *Clematis* species also occur here. Most of these species do not occur at Hoxton Park. At Appin, along the Appin-Campbelltown Road where there is a conspicuous outlier of Spotted Gum Forest, the understorey is much denser than at Hoxton Park and includes tall shrubs of *Acacia decurrens* and *A. implexa* and low shrubs of *Olearia viscidula* and *Lissanthe strigosa.*

Spotted Gum Forest is floristically similar to both the *E. moluccana - E. tereticornis* woodland and the *E. moluccana - E. crebra* woodland. It grades into the former on the lower slopes of hills around Hoxton Park and the latter on the lower slopes of the uplifted plateau west of Camden. The gradation is indistinct as many species are common to these communities. At some sites at Werombi it also grades into the Turpentine Forest. Again the transition is indistinct as many species overlap. *Eucalyptus maculata* also occurs along the Warringah Peninsula. However the Warringah Spotted Gum Forest is found in much wetter sites and has a much more mesic group of understorey species.

Most of the Cumberland Plain Spotted Gum Forest has been cleared, but in the past where small patches remained, the understorey usually remained as native pasture. Increasingly now, pasture improvement with exotic species is eliminating native species, which previously survived despite grazing. Much of the area has been subdivided for 'hobby farms', increasing the impact on natural remnants, but there are relatively undisturbed stands on some of the steeper slopes around Hoxton Park and smaller patches around Werombi, again on the steeper slopes. There is also a small stand on Water Board land on the southern side of Prospect Reservoir. Appin is also an important site for conservation as it provides a wildlife corridor between the Nepean and Georges River systems. No areas have been preserved in any Nature Reserve or National Parks and the small areas that exist in council reserves have generally been cleared of their native understorey and replaced with mown grass.

Map unit 9c - Ironbark Forest

Open-forest: *Eucalyptus crebra - Eucalyptus fibrosa*

This community is found on remnants of Wianamatta Shale along the Lapstone Monocline near Euroka, south of Glenbrook at Little Mountain, south of Bents Basin (Benson *et al.* 1990) and at Silverdale. The dominant trees are ironbarks, *Eucalyptus crebra, E. beyeriana* and *E. fibrosa.* At Little Mountain *E. punctata, E. eugenioides* and *Allocasuarina torulosa* also occur. There is an understorey of grasses and scattered shrubs of *Daviesia ulicifolia.* The vegetation contrasts with the surrounding Hawkesbury Sandstone vegetation but appears to differ somewhat from the vegetation on nearby Wianamatta Shale, along the Great Western Highway between Glenbrook and Springwood. Though much of the vegetation has been cleared for urban development, *Syncarpia glomulifera* appears to have been a major constituent of the vegetation near Springwood.

Map unit 9d - Shale/gravel Transition Forest

Open-forest: *Eucalyptus fibrosa - Eucalyptus moluccana*

This community occurs on the transitional zone between Wianamatta Shale and Tertiary alluvium (including gravel sediments), mainly between Penrith and Windsor. It contains a mixture of species found on these two areas. *Eucalyptus fibrosa*, one of the most common species on Tertiary alluvium, and *E. moluccana*, a common species on Wianamatta Shale, are the main dominants. Other tree species are *E. eugenioides* and *E. sclerophylla*. The understorey is dominated by low shrubs with a mixture of the hardier species from the Wianamatta Shale and Tertiary alluvium. *Bursaria spinosa, Daviesia ulicifolia, Dillwynia juniperina, Hardenbergia violacea, Exocarpos cupressiformis, Melaleuca nodosa* and *Acacia parramattensis* are the most common species. Small trees of *Melaleuca decora* are often conspicuous. A small patch of the community is protected in Longneck Lagoon Field Studies Centre at Pitt Town, and includes a small population of the rare shrub *Acacia pubescens*.

Map unit 9e - Castlereagh Ironbark Forest

Open-forest: *Eucalyptus fibrosa*

This unit, together with map units 14a, 14b, 14c, and the transitional 9d make up the Castlereagh Woodlands of Benson & Howell (1990*a* & *b*). Their conservation is one of the most critical issues for long-term planning for western Sydney.

On deep, well-drained reddish clay soils of the Tertiary alluvium around Castlereagh Ironbark open-forest is prominent. The best remaining stands are in Castlereagh State Forest where trees are up to 25 m high. *E. fibrosa* is the dominant tree species, generally forming pure stands, but may also be associated with *E. sideroxylon* and *E. crebra*, though these may be overlooked, since they are ironbarks with similar appearance to *E. fibrosa* and certainly much less common. In measured stands *E. fibrosa* made up about 43% of total basal area but only 21% of total plant density (Table 4). The bulk of density (69%) and 44% of total basal area is made up by *Melaleuca decora* which generally forms a small tree layer, (60–80% of the stems are less than 10 cm d.b.h.). Stems of *E. fibrosa* are now mostly 11–20 cm d.b.h. but much larger stems would once have been common.

An understorey of sclerophyllous shrubs up to 2 m high is generally associated with the pure stands of *E. fibrosa*. No particular species predominates, though the pea family Fabaceae is well represented. Shrub species which may be locally abundant

Table 4. Basal area and density of major tree species from 6 sites in *Eucalyptus fibrosa* open-forest.

	Basal area (m²/ha)			Density (plants/ha)		
	mean	(± s.e.m.)	% of total area	mean	(± s.e.m.)	% of total density
Melaleuca decora	5.1	1.7	44	470	183	69
Eualyptus fibrosa	4.9	1.3	43	145	31	21
Total	11.5	2.5		679	184	

Other species contributing to total basal area are the trees *Eucalyptus crebra, E. eugenioides, E. moluccana, E. sclerophylla, E. tereticornis* and the small trees *Angophora bakeri* and *Hakea sericea*.

are *Dillwynia tenuifolia, Dodonaea filifolia, Hakea sericea, Melaleuca nodosa, Mirbelia rubiifolia* and *Pultenaea villosa*. Less conspicuous, but frequent ground layer plants, are *Lissanthe strigosa, Cheilanthes sieberi, Brunoniella australis, Pratia purpurascens, Lepidosperma laterale* and *Dianella revoluta*. A number of species are of particular interest: *Micromyrtus minutiflora* (Myrtaceae); *Dillwynia tenuifolia*; *Pultenaea parviflora* (Fabaceae); *Grevillea juniperina* (Proteaceae); and *Dodonaea falcata* (Sapindaceae), including a number of local endemic species and forms (see Benson & McDougall 1991). For a species list for Castlereagh State Forest see Forestry Commission of NSW (1984).

This community usually grades into *E. sclerophylla - Angophora bakeri* woodland (map unit 14a) where the soil becomes more sandy, or into the *E. fibrosa - E. moluccana* open-forest (map unit 9d) on adjacent Wianamatta Shale.

The Tertiary alluvium provides very poor agricultural soils and there has been little serious agricultural usage. Recent increases in hobby farm and suburban development, and extensive gravel and clay extraction, are now leading to the clearing of much of the original vegetation. Good stands of *E. fibrosa* remain in Castlereagh State Forest, and although selective logging has altered the former open-forest structure, the floristic composition of the community is essentially undisturbed. It is highly desirable that the Forestry Commission manage this area as a conservation reserve. There is also an area of this community in Windsor Downs Nature Reserve though it is less diverse here than at Castlereagh. The *E. fibrosa* open-forest is a robust community, tolerant of most likely above-ground adjacent disturbances. Although rubbish dumping has been prolific in many areas, there is little sign of any major weed invasion problems. The shrub understorey may be reduced to a grassy understorey if an over-frequent fire regime is imposed.

Map unit 9f - River-flat Forest

Open-forest: *Angophora subvelutina - Eucalyptus amplifolia*

The floodplain of the Nepean–Hawkesbury River was the site of the first major intensive agriculture by the early european settlers. The River acquired two names as a result of being 'discovered' from two different directions; it is the Nepean above the Grose junction near Yarramundi, and the Hawkesbury below. The original distribution of vegetation related to floodplain topography. The levee banks along the river, and the back swamps beyond, produced a floodplain with tall open-forest on the well-drained crest and upper slopes of the levee bank adjacent to the river, and various sedge, rush and reed swamps in the depressions between the levee bank and sandstone cliffs (Benson 1974; Benson & Howell 1990*a* & *b*).

Between Richmond and Windsor, and on the levee banks along the Hawkesbury River downstream from Windsor, where the floodplain narrows, the levee bank forest was composed of trees over 30 m high. In 1791 John Hunter, standing on the banks of the Hawkesbury River near Richmond wrote, 'the banks are high, and the soil a light sand, but producing fine straight timber' (Hunter 1793). The largest trees were on the levee banks along the main channels of the river; smaller trees were associated with the poorly drained back-swamps. Referring to the lands of the Hawkesbury, Hunter and Shoalhaven Rivers, James Atkinson (1826) wrote 'Most of the alluvial lands were originally forest; the timber was large, principally blue and flood gum, [he could be referring to *Eucalyptus tereticornis, E. saligna* or *E. deanei*] with an abundance of the tree known in the Colony by the appellation of the apple tree, [either *Angophora subvelutina* or *A. floribunda*] which is of little value'. Today, remnant trees along the floodplain indicate that *Eucalyptus tereticornis, E. deanei* and *Angophora floribunda* were originally the main forest tree species along the Hawkesbury.

The forest understorey appears to have been shrubby, and particularly dense. Evidently it made travelling difficult, as Hunter describes. 'The person who was charged with counting his paces, and setting objects to which they directed their march, had hitherto gone first; but the long sedge [*Gahnia, Lomandra longifolia*], the dead branches which had fallen from the trees, the nettles [*Urtica incisa*], and a weed resembling ivy which entangled the feet [*Smilax australis?*], made walking on, or near the banks of the river very fatiguing' (Hunter 1793).

There would have been a fringe of *Casuarina cunninghamiana* subsp. *cunninghamiana* along the water's edge and *Casuarina cunninghamiana* forest with occasional individuals of *Angophora subvelutina* was also found on islands of sand and gravel in the Nepean River between Penrith and Richmond. This has now been virtually destroyed by sand and gravel extraction, but remnant trees, up to 18 m high, indicate the original open-forest structure. Because of the scouring effects of floods, there would have been multistemmed shrubs of *Leptospermum polygalifolium* and *Tristaniopsis laurina*, which would have survived best on outcrops of boulders and gravel, now largely removed, that would have provided secure rooting. These species are still found in the Nepean Gorge upstream from Bents Basin. Other species would probably have been *Acacia binervia, Acacia floribunda, Goodenia ovata* and *Persicaria* species. A number of *Acacia* species, *A. floribunda, A. elata, A. binervia, A. ulicifolia, A. obtusifolia* and *A. parvipinnula* together with *Bossiaea rhombifolia, Pultenaea flexilis* and *Kennedia rubicunda* have been recorded colonising disturbed sand deposits at Penrith. With the exception of *Acacia binervia* and *A. floribunda*, mature plants of these species are rarely found in *Casuarina cunninghamiana* open-forest as young plants may be washed away by floodwaters before they can be properly established.

On sites sheltered by the steep-sided sandstone cliffs, particularly downstream from Sackville, there were pockets of low dense-forest with small trees and shrubs, many of 'rainforest type' species. They included small trees of *Acmena smithii, Trema aspera, Ficus coronata, Duboisia myoporoides, Backhousia myrtifolia* and *Tristaniopsis laurina*. Vines *Eustrephus latifolius, Geitonoplesium cymosum* and *Pandorea pandorana* twisted among the shrubs, while on the ground, clumps of ferns, commonly *Doodia aspera* and *Adiantum aethiopicum*, grew in the restricted light in the moist litter layer. Where moisture and shelter were less favourable, a more open shrub layer of *Leptospermum polygalifolium* and bipinnate wattles such as *Acacia parramattensis, A. decurrens* and *A. filicifolia* was present. Ground cover was *Pteridium esculentum* and native grasses. *Lomandra longifolia* was frequent, particularly on the river banks.

On the alluvial flats of the river upstream of Richmond, where the river becomes the Nepean, and tributary creeks, the predominance by *Eucalyptus tereticornis* gradually changed to predominance of *Eucalyptus amplifolia* subsp. *amplifolia* and *Angophora subvelutina*. Phillips (1947) described these species as occurring as far down the Hawkesbury River as Sackville, but Benson (1974) regarded the vegetation on the alluvial flats between Richmond and Sackville as *Eucalyptus tereticornis* tall open-forest. Because the original vegetation in this area has been almost completely destroyed, and the two communities were very similar, it is now impossible to give exact boundaries, though it is likely the two communities intergraded between Agnes Banks and Windsor.

The fringing forest along the Nepean River had some characteristic species. Peter Cunningham (1827) wrote 'The banks of the Cow-pasture river near Narellan are high, sandy, and clothed with goodly gum-trees, swamp oaks and scrubby brushwood'. The water's edge was probably lined with *Casuarina cunninghamiana* and occasional *Tristaniopsis laurina*. More localised tree species included *Eucalyptus viminalis, E. botryoides-saligna* intergrades, *E. elata, E. benthamii, E. baueriana* and *E. bosistoana*.

Eucalyptus viminalis and *E. botryoides-saligna* were found along the Nepean between Menangle and Camden, with *E. elata* common as far downstream as Wallacia. *Eucalyptus benthamii* occurred occasionally as far down as the junction with the Grose River although it is now restricted to the Cobbitty-Wallacia section. Of *Eucalyptus baueriana* Woolls (1880) wrote 'in the County of Cumberland on the banks of the Georges River, the Nepean, and the Hawkesbury, it is a tree of very moderate size ... I have found a tree of this species occasionally amongst forest-trees in the neighbourhood of Liverpool and Richmond but its proper habitat is near the banks of rivers and creeks. It does not occur as far as I have been able to ascertain, near Sydney or Parramatta'. It is a tree of slow growth and there are some large old specimens along the Nepean River at Camden Park. *Eucalyptus bosistoana* was probably always rare along the Nepean. A localised occurrence was also found at Milperra on the Georges River.

Though most of the forest on the Nepean River floodplain would have been of *Eucalyptus amplifolia* subsp. *amplifolia* and *Angophora subvelutina*, the closely related *Angophora floribunda*, appears to have replaced *Angophora subvelutina* along the smaller, slower-flowing Cumberland Plain creeks such as South, Kemps and Badgerys Creeks. There is also some intergradation between these two species.

The understorey of the floodplain forests would probably have had a discontinuous shrub layer of *Bursaria spinosa*. Paperbarks, *Melaleuca linariifolia, M. decora* and *M. styphelioides*, with a ground cover of *Juncus* species, chiefly *J. usitatus*, or sedges, were found in periodically waterlogged depressions. Along the river banks were denser shrubs; Peter Cunningham's 'scrubby brushwood' on the banks of the Nepean would have included *Acacia binervia, Tristaniopsis laurina, Backhousia myrtifolia, Acmena smithii, Acacia floribunda, Melia azedarach* and *Trema aspera*. Smaller shrubs would have included *Hymenanthera dentata, Phyllanthus gunnii, P. gasstroemii, P. similis, Goodenia ovata, Duboisia myoporoides, Calomeria amaranthoides*, and ground-cover plants, *Microlaena stipoides, Stipa verticillata, Geranium homeanum, Pratia purpurascens, Adiantum aethiopicum* and *Pellaea falcata. Phragmites australis* was common along the Nepean River near Penrith in 1860, and is still common there.

Where the river passes through sandstone gorges south of Penrith the alluvium vegetation is very restricted. A fringe of *Casuarina cunninghamiana* and *Angophora subvelutina* with *Eucalyptus deanei* on the lower slopes is common. The gorge above Bents Basin has woodland of *Tristaniopsis laurina* and *Casuarina cunninghamiana* (Benson *et al* 1990). On a boat trip from Penrith upstream to the Nepean Gorge, George Bennett (1860) observed amongst other things on the banks 'some Red Cedar-trees (*Cedrela Australis*) [now *Toona ciliata*], now becoming very rare to the colony; the largest was about 16 feet in height'. How widespread Red Cedar was originally on the floodplain is unknown though it was probably restricted to the banks of the Nepean and Hawkesbury. Bennett's trees were obviously young saplings and indeed there are still a couple of trees near the junction with Euroka Creek. No other Red Cedar trees appear to remain on the floodplain now, though *Melia azedarach*, White Cedar, a related native species, is still common along the Nepean and Hawkesbury river banks, and has been planted widely in the district.

On the smaller floodplains of the creeks, *Casuarina glauca* frequently formed dense stands, particularly where the watercourse was sluggish or intermittent. Clumps of small trees are often the result of its root-suckering nature. This species is characteristic of saline estuarine situations, often associated with mangrove and saltmarsh and its distribution may be related to the presence of the saline ground water found below much of the Wianamatta Shale country, particularly in the low lying central basin of the Cumberland Plain (Old 1942). Subsurface salt concentrations here are considered to be much higher than that suitable for crops and gardens and could be expected to affect native vegetation in low-lying sites. High salinities were noted in the early nineteenth century and are not necessarily a result of poor land use (Old 1942).

The River-flat Forests occupied some of the most fertile agricultural land in the Sydney area, land that has been farmed since the 1790s and most of the original vegetation has now been cleared. In most situations all that remains now are a few scattered old trees surrounded by improved pasture. As early as 1826, James Atkinson was writing, 'The greater part of the alluvial lands upon the Hawkesbury and Nepean have been cleared, and are under cultivation'. Old photos and paintings of the Hawkesbury in the late nineteenth century show an agricultural landscape similar to that of today.

Scattered remnants survive along the lower Hawkesbury below Windsor and tributary creeks such as Wheeny Creek. The main area mapped is at Agnes Banks on the Hawkesbury Campus of the University of Western Sydney, where a remnant of open-forest of *Angophora subvelutina - E. amplifolia* subsp. *amplifolia* associated with important wetland species survives. This area was recommended for preservation by Forster *et al.* (1977) and may become part of a joint conservation agreement between the National Parks & Wildlife Service and the University. No other examples of this type of forest in the area have been reserved. Small patches of open-forest with *E. tereticornis,* often surviving as quite large trees may be found in narrow valleys near Ebenezer and Cattai. At Kemps Creek, where *E. amplifolia* and *Casuarina glauca* forest are found along the creek, the latter appears to indicate salinity in the ground water. In other places *Casuarina glauca* forms pure stands, often as a result of its ability to root-sucker.

Along the Georges River was similar floodplain forest. Along Williams Creek near where it joins the Georges River are alluvial soils with floodplain forest with trees of *Angophora floribunda, Eucalyptus tereticornis, E. moluccana* and some less common *Eucalyptus baueriana.* This species was once common on the alluvium of the Georges River between Liverpool and Milperra, but has mostly been cleared. Where it remains, as at Deepwater Park, Milperra, it is now mown parkland where there are no chances of natural populations of seedlings establishing to replace it. Park management systems need to be appropriately changed to ensure its conservation.

Similarly small, often weed-infested, remnants occur sporadically along the Nepean–Hawkesbury River. Though often degraded these areas may contain local populations of the native species. The flora of these river-flats and floodplains disappeared very quickly after colonisation. As a result we have little idea of the interactions between native species, flood dispersal and the particular ecological adaptions that may have been involved. Rivers and creek systems are often recommended for protection as corridors for wildlife to allow propagule and genetic interchange, in otherwise developed environments. Such areas will need rehabilitation and the re-establishment of appropriate native vegetation if they are to be successful wildlife corridors. The protection of remaining native populations along creeks and rivers, particularly the Nepean-Hawkesbury will be essential if sources of appropriate material are to be available. The ephemeral nature of many native floodplain species means that their transitory habitats must be protected even when species are apparently absent.

Map unit 9o - Turpentine-Ironbark Forest

Open-forest: ***Syncarpia glomulifera - Eucalyptus paniculata* subsp. *paniculata***

On the eastern edge of the map area near Bankstown are remnants of the Turpentine-Ironbark Forest originally found on moderate rainfall Wianamatta Shale soils further east. Tree species in Bankstown remnants include *Syncarpia glomulifera, Eucalyptus fibrosa* and *E. globoidea*. There is a mixing of species from the Cumberland Plain Woodlands - *Eucalyptus moluccana-E. tereticornis* dominated - of the drier shale areas the understorey contains species from both areas. There are also some interesting sites (for example, The Crest of Bankstown) with rainforest species such as *Euodia micrococca, Achronychia oblongifolia* and *Rhodamnia rubescens*.

Sydney Sandstone Complex (map units 10ag & 10ar)

This is the widespread vegetation complex found on the Hawkesbury Sandstone areas of the sheet. It occurs widely on the coastal plateaus up to 800 m elevation. It contains considerable local structural and floristic variation depending particularly on topographic position, local soil texture, drainage and aspect. Two broad subunits, have been recognised from aerial photos. These are a moist forest type, generally associated with sheltered hillsides and moist *gullies* (map unit 10ag) and a dry woodland type, generally associated with dry plateaus and *ridges* (map unit 10ar). The units have been used on the Katoomba and Wallerawang map sheets. On the lower Blue Mountains however this pattern is complicated by the presence of extensive areas of ridgetop with soils influenced by the Wianamatta Group and the Mittagong Formation, located stratigraphically between the lowest unit of the Wianamatta Group shale and the Hawkesbury Sandstone. Such areas occur for example on the Oakdale Tablelands, south of Glenbrook, Winmalee and near Bowen Mountain (Bannerman & Hazelton 1990). Soils here are yellow podzolics belonging to the Lucas Heights soil landscape, are deeper and more clayey than found on the Hawkesbury Sandstone elsewhere and support open forest vegetation. Because much of this area is within national parks and, because of its rugged terrain, difficult of access, much less field checking has been carried out in comparison with Cumberland Plain region.

Descriptions of most of the common Blue Mountains species are given in Baker *et al.* (1984, 1985) and a list of species occurring in sandstone areas on the margins of western Sydney is included in Benson & McDougall (1991).

Map unit 10ag - Sydney Sandstone Gully Forest

i) Tall open-forest: ***Eucalyptus deanei* or *E. saligna - Angophora floribunda - Syncarpia glomulifera***

ii) Closed-forest: ***Ceratopetalum apetalum - Doryphora sassafras***

iii) Open-forest: ***Eucalyptus piperita - Angophora costata***

Sandstone Gully Forest is generally confined to gullies and sheltered hillsides, particularly on southern to eastern aspects. There are extensive areas around Kurrajong Heights and along creeks flowing southward to the Grose, apparently due to the high rainfall in the area (over 1 200 mm p.a.), the steep sheltered gorges along the tributaries of the Grose and enrichment from the shale soils on the ridges. It is less extensive south of the Grose River where annual rainfall is less than 1 000 mm.

Vegetation structure ranges from open-forest to tall open-forest and closed-forest. Floristic variation is considerable. Floristic groups may be recognised but there is considerable intergrading between these. Major gradients relate to increasing moisture, shelter and soil fertility. Closed-forest occurs where these three factors are combined to form favourable conditions. Major vegetation groupings are:

i) Tall open-forest: *Eucalyptus deanei* or *E. saligna - Angophora floribunda - Syncarpia glomulifera*

This vegetation is confined to valley floors or lower sheltered slopes where moisture, shelter and soil fertility are high. It occurs along major watercourses such as the Grose River, and creeks of the lower Blue Mountains as well as along Cattai and Little Cattai creeks near Maroota. *Eucalyptus deanei* and the closely related *E. saligna* rarely occur together. *Eucalyptus deanei* is more common in the lower Blue Mountains, *E. saligna* in the Cattai-Maroota area. Other tree species are *Angophora floribunda* and *Syncarpia glomulifera*. Associated species include shrubs, *Backhousia myrtifolia, Acacia elata* and *Allocasuarina torulosa*, scramblers, *Cissus hypoglauca, Cissus antarctica, Morinda jasminoides* and *Smilax australis* and ferns, *Calochlaena (Culcita) dubia, Doodia aspera* and *Pellaea falcata*.

ii) Closed-forest: *Ceratopetalum apetalum - Doryphora* sassafras

Small patches of closed-forest rainforest vegetation with *Livistona australis* occur on sheltered southerly aspects in the Kurrajong area around Mountain Lagoon and Wheeny Creek.

iii) Open-forest: *Eucalyptus piperita - Angophora costata*

This is the widespread vegetation of gullies and sheltered slopes on sandstone with annual rainfall generally greater than 1 000 mm.

The main trees are *Eucalyptus piperita* and *Angophora costata* but *Eucalyptus pilularis* may be locally abundant on more fertile sites. *Allocasuarina torulosa* is a common smaller tree. The understorey is dominated by a variety of shrubs, 0.5–2 m high, the main families being Proteaceae, Fabaceae and Myrtaceae. Common species include *Grevillea linearifolia, Pultenaea flexilis, Acacia terminalis*, single-stemmed form of *Hakea dactyloides* and *Persoonia linearis*. There is a distinctive shrub flora along creeks, including the species *Tristaniopsis laurina, Backhousia myrtifolia, Ceratopetalum apetalum* and *Callicoma serratifolia*.

Sandstone Gully Forest of *Eucalyptus piperita* and *Angophora costata* together with *E. pilularis* occurs on sheltered hillsides in the north-eastern corner of the map sheet (Benson & Howell 1990*a*). On the lower Blue Mountains there are extensive areas of open-forest around Kurrajong Heights and along creeks flowing southward to the Grose. These are responding to the high rainfall in the area (over 1 200 mm), the deep sheltered gorges along the tributaries of the Grose and enrichment from the shale soil on the ridges. *Eucalyptus sieberi* probably indicates well-drained but poorer soils. Rodd (1987) describes open-forest of *Eucalyptus piperita, E. sieberi* and *Angophora costata* with some *E. cypellocarpa* or *E. agglomerata* as occurring over large areas of drier or less fertile (in comparison with the basalt soils) lower slopes of Mount Tomah to the west of the map sheet area and a little higher in elevation, but similar vegetation occurs on sandstone hillsides near Bilpin and Kurrajong Heights.

On the lower Blue Mountains south of the Grose, rainfall tends to be lower and gully vegetation less mesic. Rainfall at Springwood is just over 1 000 mm p.a. and at Warragamba it is 970 mm p.a. Sandstone Gully forest at Bents Basin includes *Eucalyptus pilularis* and *Syncarpia glomulifera* with *Ceratopetalum apetalum* and *Backhousia myrtifolia* along perennial creek lines (Benson, Thomas & Burkitt 1990). There is a sparse shrub understorey consisting mainly of *Bossiaea rhombifolia, Persoonia linearis* and *Leptospermum trinervium (attenuatum)*.

Map unit 10ar - Sydney Sandstone Ridgetop Woodland

i) Low open-forest: ***Eucalyptus sieberi - Eucalyptus piperita***

ii)Woodland/
open-woodland: ***Eucalyptus gummifera - Eucalyptus eximia - Angophora costata - Angophora bakeri - Eucalyptus sparsifolia***

iii) Open-forest/
woodland: ***Eucalyptus gummifera - Angophora costata - E. notabilis - E. sparsifolia - E. punctata - Syncarpia glomulifera***

iv) Open - scrub: *Angophora hispida* (see also Map unit 21f)

Like the Sandstone Gully Forest, the Sandstone Ridgetop Woodland is considerably variable both structurally and floristically. Structure ranges from open-forest to woodland, open-woodland, low woodland, scrub and heath. Major gradients are apparently related to rainfall and soil texture, in particular to sand and clay content. These also influence drainage conditions and add local variation to broader trends. Some tree species occur over a wide range of conditions - *Angophora costata, Eucalyptus gummifera, E. sparsifolia, E. piperita* for example are ubiquitous. Other species are more likely to indicate particular conditions - *Syncarpia glomulifera* and *Eucalyptus punctata* may indicate clay soil influence, *Angophora bakeri* and *Eucalyptus eximia*, low rainfall well drained sites, *E. sclerophylla* - damp shallow soils, *Eucalyptus sieberi*- well drained sites with higher rainfall.

Ridge and plateau vegetation has a rich, sclerophyllous, shrubby understorey with species of Proteaceae, Fabaceae, Epacridaceae and Myrtaceae. Shrub and ground cover species may be better indicators of local conditions though again there are very widespread species such as *Leptospermum trinervium, Lambertia formosa* and *Isopogon anemonifolius*. Some major species groupings can be recognised and related in particular to soil and rainfall conditions but there is considerable intergradation and local variation within them. They do however serve as a guide for understanding vegetation and landform. Detailed studies of plant response to soil and rainfall gradients are needed to confirm these exploratory hypotheses.

i) Low open-forest: ***Eucalyptus sieberi - Eucalyptus piperita***

Rodd (1987) describes low open-forest with *Eucalyptus piperita, E. sieberi, E. burgessiana* and *E. stricta* in various combinations together with scattered occurrences of *E. oblonga* and *Angophora costata* for the tops of sandstone spurs around Mount Tomah. Soils are mostly very shallow, associated with rock ledges, often poorly drained and highly infertile. Similar vegetation occurs widely north of the Grose River, but south of the Grose *Eucalyptus sieberi*, in particular, is less common. This probably relates to the higher annual rainfall in the Kurrajong area (above 1 200 mm p.a.) compared with elsewhere in the lower Blue Mountains. *Eucalyptus sieberi* occurs again on the coast where rainfall is again higher. Common shrub species listed by Rodd include *Banksia ericifolia, B. spinulosa, Lambertia formosa, Isopogon anemonifolius, Hakea dactyloides, Leptospermum trinervium (attenuatum), L. polygalifolium (flavescens), Platysace linearifolia, P. lanceolata, Dillwynia floribunda* and *Epacris microphylla*.

ii) Woodland/
open-woodland: ***Eucalyptus gummifera - Eucalyptus eximia - Angophora costata - Angophora bakeri - Eucalyptus sparsifolia***

This vegetation is found on dry hillsides and ridges on the lower Blue Mountains generally south of the Grose River. These areas appear to be drier than those with *E. sieberi - E. piperita* low open-forest with an annual rainfall of less than 1 000 mm per annum. Soils are earthy sands or yellow earths with a depth of 50–100 cm belonging to the Faulconbridge, Hawkesbury and Gymea soil landscapes (Bannerman & Hazelton 1990). Understorey is shrubby with species such as *Leptospermum trinervium, Hakea sericea, Grevillea buxifolia, Baeckea diosmifolia, Leucopogon muticus* and *Persoonia levis.* Patches of mallee eucalypts, including the restricted species *Eucalyptus burgessiana* and *E. multicaulis,* are frequent along ridges running north from Springwood, and with *E. consideniana* along the Woodford Range.

Sandstone country drained by Cattai, O'Haras and Little Cattai Creeks in the north-eastern corner of the map sheet has woodland with *Eucalyptus haemastoma, E. sclerophylla, E. gummifera, E. eximia, E. punctata, Angophora costata* and *A. bakeri.* Sclerophyllous understorey shrubs include species of *Banksia, Grevillea, Hakea, Boronia, Leptospermum* and *Pultenaea* (Benson & Howell 1990*a*).

In the south-east corner of the sheet around East Hills and Holsworthy woodland trees include *Eucalyptus sclerophylla, E. punctata, E. piperita* and *Angophora bakeri.* The understorey has a variety of shrub species including *Acacia terminalis, Grevillea sericea, Banksia spinulosa* var. *spinulosa* and *Philotheca salsolifolia.*

iii) Open-forest/
woodland: ***Eucalyptus gummifera - Angophora costata - Eucalyptus notabilis - Eucalyptus sparsifolia - Eucalyptus punctata - Syncarpia glomulifera***

This vegetation is found on Hawkesbury Sandstone on sites with a clay influence. In the lower Blue Mountains these soils are found on ridgetops and have developed from the Mittagong Formation at the stratigraphic junction between the Wianamatta Shale and the Hawkesbury Sandstone. Soils are yellow podzolics and belong to the Lucas Heights soil landscape.

Other sites with a clay influence may be due to shale lenses in the Hawkesbury Sandstone or residual areas of Wianamatta Shale. The latter areas generally have distinctive Ironbark Forest (mapped as unit 9c).

Species such as *Syncarpia* are generally good indicators of clay soils, though other tree species may occur in a wide range of sites. Understorey species tend to be better site indicators and species such as *Bossiaea obcordata, Grevillea mucronulata, Cyathochaeta diandra* and *Entolasia stricta* are characteristic.

Woodland communities at Bents Basin are influenced by shale residuals (Benson *et al.* 1990) and a variety of species occur including *Eucalyptus gummifera, E. eximia, Angophora costata, E. pilularis* and *E. punctata. Lambertia formosa, Persoonia linearis, Leptospermum trinervium* and *Leucopogon muticus* are common shrubs.

iv) Open - scrub: Angophora *hispida* (see also Map unit 21f)

Within the ridge-top woodland, particularly shallow soils support open-scrub with *Angophora hispida;* patches are found particularly around Annangrove and Maroota. Localised areas of open-heath, open-scrub and sedgeland are mapped separately as communities 21f and 26a respectively.

Map unit 10c - Grey Box Woodland

Woodland: ***Eucalyptus moluccana - Eucalyptus tereticornis***

Grey Box Woodland is found on the flat to gently undulating country that makes up much of the dry central Cumberland Plain core, between Parramatta and Penrith with a rainfall of 700–800 mm p.a. It is part of the *Eucalyptus hemiphloia* [=*moluccana*] - *E. tereticornis* association of Pidgeon (1941) and Phillips (1947) which has been here divided into a number of units, the most important being the Grey Box Woodland (map unit 10c) and the Grey-Box-Ironbark Woodland (map unit 10d). This unit and the following map unit 10d, together with Spotted Gum Forest make up the Cumberland Plain Woodland of Benson & Howell (1990*a* & *b*).

Governor Arthur Phillip (1789) described country to the west of Parramatta in April 1788. 'The country through which they travelled was singularly fine, level, or rising in small hills of a very pleasing and picturesque appearance. The soil excellent, except in a few small spots where it was stony. The trees growing at a distance of from 20 to 40 feet [6–12 m] from each other, and in general entirely free from brushwood, which was confined to the stony and barren spots'. This description of the Grey Box Woodland indicates it to have originally been an open community of park-like appearance, with well spaced, large, spreading trees and an understorey mainly of tussock grasses and herbs, and localised patches of denser scrub. The 'stony and barren spots' with 'brushwood' are probably ironstone residuals or gullies in Hawkesbury Sandstone which would have had a dry shrubby understorey.

John White (1790), on the same expedition wrote 'The country here about [near Greystanes Hill] was pleasant to the eye, well wooded, and covered with long sour grass, growing in tufts. At the bottom of this valley or flat, we crossed another watercourse, and ascended a hill, where the wood was so very thick as to obstruct our view'.

Similarly, John Hunter (1793) writes 'The country about Rose Hill, [near Parramatta], which I have formerly mentioned as requiring not much labour in clearing, from its being covered only with lofty, open woods, without any underwood, and which I then observed ran to the westward about 20 miles, [32 km] has since been travelled over by several gentlemen, who admit that that kind of country does extend near the distance above-mentioned to the westward, but in a north and south direction, it does not extend more than 3 or 4 miles, [5–6 km] when you come again into barren rocky land wholly unfit for cultivation ...'. This latter country is probably on Hawkesbury Sandstone.

In describing the central basin of the Cumberland Plain, James Atkinson (1826) writes 'In the county of Cumberland, one immense tract of forest land extends, with little interruption, from below Windsor on the Hawkesbury, to Appin, a distance of 50 miles [80 km]; large portions of this are cleared and under cultivation, and of the remainder that is still in a state of nature, a great part is capable of much improvement. The whole of this tract, and indeed all the forest in this county, was thick forest land, covered with very heavy timber, chiefly iron and stringy bark, box, blue and other gums, and mahogany'.

All these writers give the impression of open, though in some places locally dense stands of trees forming a woodland (*sensu* Specht 1970) with a grassy understorey. The nature of the understorey is clearly indicated by Atkinson who defines his use of the word 'forest'. 'It is, however, always to be understood that forest means land more or less furnished with timber trees, and invariably covered with grass underneath, and destitute of underwood'.

Estimates of canopy height in remnant stands ranged from 10 to 20m and canopy cover ranges from 10 to 73%. These figures include both woodland and open-forest formations, the latter structure being found in stands with vigorous regeneration. Most sites had been disturbed in the past and except for large, old trees which were either multistemmed and showed evidence that stems had been cut, or appeared to be sapling regrowth. From Governor Phillip's (1789) estimates of tree spacing 'from twenty to forty feet from each other', a range of tree density from 68 trees/ha to 272 trees/ha can be calculated. The present mean tree density (378 plants/ha) (Table 5) is higher as a result of the denser regrowth following clearing or disturbance. The sites with low tree densities, sites 90 (3 trees), 73 (4 trees), 80 (5 trees) and 74 (5 trees) generally have larger trees.

Table 5. Basal area and density of major tree species from 31 sites in the *Eucalyptus moluccana* - *E. tereticornis* woodland.

	Basal area (m^2/ha)			Density (plants/ha)		
	mean	(± s.e.m.)	% of total area	mean	(± s.e.m.)	% of total density
Eucalyptus moluccana	5.5	1.1	39	113	21	30
E. tereticornis	4.5	1.3	32	125	29	33
E. eugenioides	1.0	0.2	7	13	7	3
Melaleuca decora	0.9	0.4	6	53	27	14
Total	14.4	1.5		378		

Other species contributing to total basal area - trees *Angophora subvelutina*, *Eucalyptus amplifolia* subsp.*amplifolia*, *E. fibrosa*, *E. longifolia*; small trees *Acacia decurrens*, *A. parramattensis*, *Angophora bakeri*, *Casuarina glauca*, *Allocasuarina littoralis*, *Melaleuca styphelioides*.

The main tree species, *Eucalyptus moluccana*, Grey Box and *E. tereticornis*, Forest Red Gum, today make up over 70% of the total basal area and 60% of the total stem density of sites examined (Table 5). The total basal areas and stem densities of the two species are about equal but they occur together in varying proportions. *E. moluccana* appears to favour the higher topographic situations of upper slopes and rises and *E. tereticornis* favours lower slopes and depressions. There was a negative correlation ($r = -0.43$, 23 d.f. $p < 0.05$) between them based on basal area data.

Less common tree species are *E. fibrosa*, which is generally found near the edge of the mapped community, perhaps on sandier sites, *E. longifolia* which occurs sporadically, its main occurrence being in the Grey Box-Ironbark Forest further east, and *E. amplifolia* and *Angophora subvelutina* which are confined to creek channels or poorly-drained sites. *E. amplifolia* replaces the very closely related species *E. tereticornis* on such sites. Small trees of *Casuarina glauca* and *Melaleuca decora* are found in similar impeded drainage situations.

The understorey may be shrubby or grassy depending on disturbance or grazing intensity. Evidently there was considerable local variation in the type of understorey even in the earliest days. John Macarthur wrote to Governor King in 1804 (Historical Records of Australia 5, 583) concerning the pasture value of land in the vicinity of Prospect. 'I have not seen any unappropriated range of 5,000 acres [2,000 ha] that contains 500 acres [200 ha] of dry pasture on which I should think it safe to feed sheep ... I carefully examined a tract from near George's River to the Nepean, and from thence to the South Creek and Prospect Hill, but entirely without success. Almost the whole is of that wet kind which has been found so fatal to sheep, or is covered with scrubby brushwood'. The 'wet kind' of land probably caused sheep losses through liver fluke or foot rot and would have been partly covered with stands of *Casuarina glauca* or *Eucalyptus amplifolia* subsp *amplifolia*, found on poorly-drained land. 'Scrubby brushwood' here may refer to the stands of *Melaleuca decora* which are still common west of Liverpool.

The main shrub species now is *Bursaria spinosa* which grows in both dense clumps or as scattered individuals. It was found at every site and densities, recorded from a limited number of sites, ranged from 100 to 1 000 plants/ha. Density may be related to grazing or burning patterns as undisturbed sites carry the densest stands. In 1817 the botanist Allan Cunningham, on visiting the farm of a friend near Liverpool wrote, 'Like other farms in the neighbourhood it is overrun with the *Bursaria spinosa* now in fruit' (Lee 1925). Whether there was an increase in the abundance of *Bursaria spinosa* occurring at the time as a result of changes in grazing, cultivation, or fire management is not clear but the species has remained abundant.

Only one other shrub species, *Dillwynia juniperina*, occurred at more than 25% of the sampling sites though this, and the less common shrubs *Daviesia ulicifolia* and *Indigofera australis*, may have high densities on particular sites. Other less common shrubs, *Acacia parramattensis*, *A. decurrens* and *A. implexa* generally have much lower local densities.

European settlement both increased and decreased fire frequencies depending on the locality. James Atkinson wrote in 1826: 'In the unoccupied districts in the interior, and also in those tracts that are only used for the purposes of grazing, the grass in winter becomes withered by the frosts, and assumes the appearance of bad coloured hay; in this state it is refused by the cattle; and as it impedes the growth of young grass, the common practice is to set fire to it. The Natives also pursue the same system setting fire to the thick brushes and old grass every summer; the young herbage that springs up in these places, is sure to attract the kangaroos and other game; and the horned cattle are also very fond of feeding upon this *burnt ground*, as it is termed in the colony; ... In dry seasons these periodical burnings sometimes assumes a truly awful appearance, the country seems on fire in all directions, and if the weather is calm, is enveloped in dense smoke'. Many of the shrub species regenerate rapidly after a fire and their local abundance may have been increased by the early settlers' use of fire for clearing followed by longer periods of protection from fire. The small remnants of bush surviving now are probably only infrequently burnt.

Phillips (1947) described *Themeda australis* as the typical species of undisturbed sites together with *Dichelachne micrantha* and *Sorghum leiocladum* but that these were readily lost by overgrazing leaving *Bothriochloa macra*, *Chloris truncata*, *Eragrostis leptostachya* and *Danthonia* species predominating. Under trees *Bothriochloa* and *Chloris* were replaced by *Aristida vagans*, *A. ramosa* and *Microlaena stipoides*. Phillip's work was done at a time when the Cumberland Plain vegetation was heavily grazed. Recent patterns of subdivision and changing urban and rural development often leave areas temporarily ungrazed, and many sites recorded during the present survey were on areas no longer grazed. Species recorded were mainly perennial grasses particularly *Themeda australis* (recorded on 87% of quadrats) *Eragrostis leptostachya* (32%), *Aristida vagans* (39%) and *A. ramosa* (26%). Small herbs were also common, particularly *Dichondra repens* (90% of quadrats), *Brunoniella australis* (87%), *Lomandra filiformis* (35%), *Dianella laevis* (39%), *Oxalis corniculata group* (74%) and *Cheilanthes sieberi* (55%). Many of these sites have been subsequently destroyed.

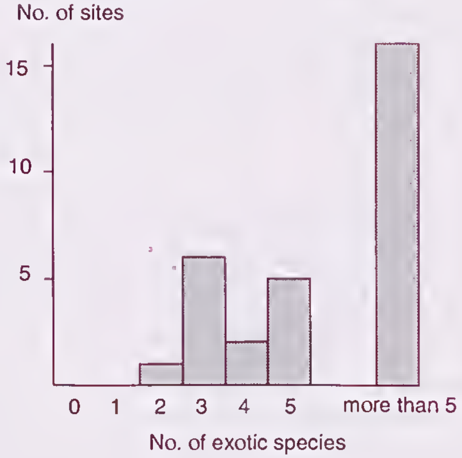
Allan Cunningham mentions some of the species between Parramatta and Liverpool in 1818. 'In my route towards Liverpool, on a line of road about 9 miles [14 km], bounded by open forest-land and confined dense brush, many interesting (already described) plants were in flower, among which I gathered the following *Pomaderris* *betulina*, flowers panicled axillary and terminal. *Diosmeoe*, habit of *Correa*, a shrub with white flowers; also a genus of this order allied to *Eriostemon*, stamina smooth, leaves oblong, narrow obtuse. *Dampiera undulata*, a suffruticose blue flowering plant [possibly *Dampiera stricta*]. *Colletia* sp., a small tufted leaved, spinous shrub, suspected to be allied to *Cryptandra* [possibly *Cryptandra amara* or *spinescens*] is now frequent, in flower and fruit, in the vicinity of the town of Liverpool. In moist situations I gathered a small plant of the order Gentianaceae, *Erythraea australis* [*Centaurium spicatum*]. To the southward of Liverpool the country is an open forest-land of common *Eucalypti*, in which *Exocarpus cupressiformis*, and the papilionaceous tree *Jacksonia scoparia*, at this period laden with yellow flowers, are very conspicuous. *Pimelea spicata* and *P. glauca* of Mr Brown; a small *Daviesia* with cordate leaves (*D. squarrosa*, Smith); with a *Helichrysum*, allied to *H. papillosum* and prevalent in this description of country ... In situations on the roadside, more or less subject to inundation, a delicate tufted *Lobelia* (*L. inundata*) is in flower, and *Ruellia australis* [*Brunoniella australis*] is common in grassy dry spots, decorating our path throughout this days route' (Lee 1925).

Cunningham's references to the Pimeleas are interesting. *Pimelea spicata* is now extremely rare, and now only known from a few locations in western Sydney, though it was formerly more common. Similarly *Pimelea glauca* has only been recorded from a few places in the Sydney area including Cunningham's specimen, collected 'near Liverpool' in 1818; this was presumably on the journey described above and is held

Table 6. a) Number of native exotic species recorded from sites in *Eucalyptus moluccana–E. tereticornis* woodland.

	range	mean	s.e.m.
Total number of species / site	15–46	32.7	1.3
Number of native species / site	12–41	25.8	1.2
Number of exotic species / site	2–19	6.9	0.7
Total number of native species recorded	188		
Total number of exotic species recorded	46		

b) Frequency of exotic species



at the National Herbarium of New South Wales. Perhaps Cunningham's *Pimelea* specimens from Liverpool indicate original Cumberland Plain species that were quickly exterminated by the settlers' stock grazing or other associated land use change?

Land use changes have also allowed exotic species to establish. During this study between 2 and 19 exotic species were recorded on every site (Table 6). More than half the sites had more than 5 exotic species, the most common species being *Hypochaeris radicata*, *Conyza floribunda*, *Plantago lanceolata* and *Paspalum dilatatum* (Table 7).

Though much of the vegetation that now remains has been heavily disturbed, some remnants still carry quite a large number of native species. Though a number of recommendations have been made, no areas have been preserved in any national park or nature reserve. A good example at Kemps Creek is presently being considered. Some areas have been included in council reserves but in many of these the understorey has been mowed or replaced with exotic Kikuyu grass, *Pennisetum clandestinum*.

Table 7. Exotic species recorded in *Eucalyptus moluccana* - *E. tereticornis* woodland.

	% frequency
APIACEAE	
Apium tenuifolium	11
ASCLEPIADACEAE	
Araujia hortorum	38
Gomphocarpus fruticosus	11
ASTERACEAE	
Aster subulatus	11
Bidens pilosa	50
B. subalternans	4
Circium vulgare	38
Conyza floribunda	84
Gnaphalium purpureum	4
G. spicatum	4
Hypochaeris glabra	4
H. radicata	92
Leontodon leysseri	23
Taraxacum officinale	8
CACTACEAE	
Opuntia stricta	4
CRASSULACEAE	
Kalanchoe tubiflora	4
FABACEAE	
Lotus angustissimus	8
IRIDACEAE	
Romulea rosea	11
ASPARAGACEAE	
Asparagus densiflorus	4
A. officinalis	8
Myrsiphyllum asparagoides	8
MALVACEAE	
Modiola caroliniana	11

	% frequency
OLEACEAE	
Ligustrum sinense	11
Olea europea subsp. *africana*	19
PLANTAGINACEAE	
Plantago lanceolata	80
POACEAE	
Bromus cathartieus	4
Cynodon dactylon	11
Digitaria violascens	4
Paspalum dilatatum	76
P. urvillei	4
Pennisetum clandestinum	4
Setaria geniculata	42
Sporobolus africana	27
POLYGONACEAE	
Rumex crispus	4
PRIMULACEAE	
Anagallis arvensis	8
ROSACEAE	
Rosa rubiginosa	4
Rubus vulgaris	4
RUBIACEAE	
Richardia stellaris	19
SOLANACEAE	
Lycium ferocissimum	11
Solanum mauritianum	4
S. nigrum	4
S. pseudocapsicum	4
S. sodomaeum	4
VERBENACEAE	
Lantana camara	8
Verbena officinalis	11

Table 8. The Grose Vale 'limestone flora' recorded by Carne (1908) indicating species recorded by Bill May in 1984 (pers. comm.). Soil types indicated by Carne, S = shale, I = intermediate, L = limestone; + = present in 1984. (Family names minus -aceae in brackets).

DICOTYLEDONS

Abutilon oxycarpum (Malv.)	S	+
Acacia decurrens (Fab.)	S	+
Acacia longifolia (Fab.)	S	+
Acaena novae-zelandii (Ros.)	S	
Acaena ovina (Ros.)	S	
Acmena smithii (Myrt.)	L	
Alectryon subcinereus (Sapind.)	L	+
Alphitonia excelsa (Rhamn.)	L	+
Aphanopetalum resinosum (Cunoni.)	I	+
Brachychiton populneus (Sterculi.)	I	+
Breynia oblongifolia (Euphorbi.)	I	+
Bursaria spinosa (Pittospor.)	S	+
Callistemon salignus (Myrt.)	S	+
Calotis lappulacea (Aster.)	S	
Cassia odorata (Fab.)	L	+
Cassine australis (Celastr.)	L	+
Cayratia clematidea (Vit.)	L	+
Cissus antarctica (Vit.)	L	+
Cissus hypoglauca (Vit.)	L	+
Citriobatus pauciflorus (Pittospor.)	L	+
Clematis aristata (Ranuncul.)	S	
Clematis glycinoides (Ranuncul.)	S	
Clerodendrum tomentosum (Verben.)	I	+
Croton verreauxii (Euphorbi.)	I	+
Cuttsia viburnea (Escalloni.)	L	
Daucus glochidiatus (Api.)	S	
Desmodium brachypodium (Fab.)	S	
Dichondra repens (Convolvul.)	S	
Diospyros australis (Eben.)	L	
Dodonaea viscosa (Sapind.)	S	+
Ehretia acuminata (Boragin.)	L	+
Einadia trigonon (Chenopodi.)	S	+
Endiandra ? (Laur.)	L	
Sambucus australasica (Caprifoli.)	L	
Santalum obtusifolium (Santal.)	L	
Sarcomelicope simplicifolia (Rut.)	L	
Sarcopetalum harveyanum (Menisperm.)	L	+
Senecio glomeratus (Aster.)	S	
Sigesbeckia orientalis (Aster.)	S	
Solanum prinophyllum (Solan.)	S	
Solanum stelligerum (Solan.)	S	+
Tasmannia insipida (Winter.)	L	
Trema aspera (Ulm.)	I	+
Toona ciliata (australis) (Meli.)	L	+
Urtica incisa (Urtic.)	S	
Vittadinia tenuissima (Aster.)	S	
Wahlenbergia gracilis (Campanul.)	S	+

MONOCOTYLEDONS

Aristida vagans (Po.)	S	
Bothriochloa decipiens (Po.)	S	
Carex appressa (Cyper.)	S	
Carex longebrachiata (Cyper.)	S	
Cenchrus caliculatus (Po.)	L	
Commelina cyanea (Commelin.)	S	
Cymbopogon refractus (Po.)	S	
Cynodon dactylon (Po.)	S	
Danthonia pilosa (Po.)	S	
Dianella laevis (Dianell.)	S	+
Dichanthium sericeum (Po.)	S	
Dichelacne sciurea (Po.)	S	
Echinopogon ovatus (Po.)	S	
Eragrostis leptostachya (Po.)	S	
Eustrephus latifolius (Philesi.)	S	+
Gahnia aspera (Cyper.)	S	
Gahnia melanocarpa (Cyper.)	S	
Geitonoplesium cymosum (Philesi.)	S	+
Juncus ?usitatus (Junc.)	S	

Epilobium billardierianum (Onagr.)	S	
Eucalyptus moluccana (Myrt.)	S	+
Eucalyptus tereticornis (Myrt.)	S	+
Eupomatia laurina (Eupomati.)	L	
Euodia micrococca (Rut.)	I	+
Exocarpos cupressiformis (Santal.)	S	
Ficus coronata (Mor.)	L	+
Geranium solanderi (Gerani.)	S	+
Glochidion ferdinandi (Euphorbi.)	I	+
Glycine clandestina (Fab.)	S	+
Guioa semiglauca (Sapind.)	L	+
Helichrysum diosmifolium (Aster.)	S	
Hibiscus heterophyllus (Malv.)	L	+
Hymenosporum flavum (Pittospor.)	L	+
Indigofera australis (Fab.)	S	+
Legnephora moorei (Menisperm.)	L	+
?*Lepidium ruderale* L. (Brassic.)	S	
Leucopogon juniperinus (Epacrid.)	S	+
Maclura cochinchinensis (Mor.)	L	+
Marsdenia rostrata (Asclepiad.)	L	+
Melaleuca styphelioides (Myrt.)	S	+
Melia azedarach (Meli.)	L	+
Mentha diemenica (Lami.)	S	
Myoporum debile (Myopor.)	S	
Neolitsea dealbata (Laur.)	L	
Nicotiana suaveolens (Solan.)	S	
Notelaea longifolia (Ole.)	S	
Nyssanthes erecta (Amaranth.)	S	
Pandorea pandorana (Bignoni.)	I	+
?*Passiflora herbertiana* (Passiflor.)	L	+
Phyllanthus gasstroemii (Euphorbi.)	I	
Plantago debilis (Plantagin.)	S	
Plectranthus parviflorus (Lami.)	S	+
Pratia purpurascens (Lobeli.)	S	
Pseuderanthemum variabile (Acanth.)	S	+
Rapanea variabilis (Myrsin.)	I	+
Rhodamnia rubescens (Myrt.)	L	+
Rubus hillii (Ros.)	L	
Rubus parvifolius (Ros.)	S	+
Rumex brownii (Polygon.)	S	
Leptochloa decipiens (Po.)	S	
Libertia paniculata (Irid.)	L	
Lomandra longifolia (Lomandr.)	S	
Microlaena stipoides (Po.)	S	
Oplismenus imbecillus (Po.)	S	
Panicum pygmaeum (Po.)	S	
Smilax australis (Smilac.)	S	+
?*Stipa rudis* (Po.)	S	

FERNS

Adiantum formosum (Adiant.)	L
Adiantum silvaticum (Adiant.)	L
Doodia aspera (Blechn.)	L
Pellaea falcata (Adiant.)	L

Additional species recorded by May in 1984

Acacia parramattensis (Fab.)
Celastrus australis (Celastr.)
Croton insularis (Euphorbi.)
Cupaniopsis anacardioides (Sapind.)
Ficus rubiginosa (Mor.)
Maytenus silvestris (Celastr.)
Morinda jasminoides (Rubi.)
Parsonsia straminea (Apocyn.)
Pittosporum revolutum (Pittospor.)
Polyscias sambucifolia (Arali.)
Stellaria flaccida (Caryophyll.)
Stephania japonica (Menisperm.)
Streblus brunonianus (Mor.)

Map unit 10d - Grey Box - Ironbark Woodland

Woodland: *Eucalyptus moluccana - Eucalyptus tereticornis - Eucalyptus crebra*

This community is similar to the previous woodland (Community 10c) but is found on more hilly Wianamatta Shale country with *Eucalyptus crebra* as a co-dominant species. It is part of the Cumberland Plain Woodland of Benson & Howell (1990*a* & *b*). The community was originally extensive around the edge of the Cumberland Plain, being abundant towards Camden and Picton, Kurrajong to Glossodia and Cattai to Prospect.

The understorey is generally grassy with patches of shrubs. Grass species include *Themeda australis, Eragrostis leptostachya* and *Aristida ramosa* and *A. vagans. Bursaria spinosa* is the most common shrub species, often forming dense thickets. Other, less common, shrub species include *Acacia implexa, A. parramattensis* and *Indigofera australis.* A small stand of this community is included in the Longneck Lagoon Field Studies Centre at Pitt Town.

Isolated stands of rainforest scrub vegetation have been recorded from Box Hill at Grose Vale (Carne 1910) (Table 8) and at the 'Native Vineyard' at Cobbitty (Woolls 1867). William Woolls writes: 'This spot [it is about 1 km south-west of Cobbitty Trig] is also remarkable for the occurrence of many plants which do not grow anywhere in the adjacent bush ... The 'Vineyard' as it is called [presumably named because of the predominance of vines and lianes] contains only a few acres, and is almost in sight of the Reverend T. Hassell's residence at Denbigh. It has the appearance of a cultivated shrubbery, rather than that of a collection of plants formed by natural causes'. Many of the native species are now extinct or still surviving as only one or two old plants, largely due to the invasion of *Olea europea* subsp. *africana* which forms dense scrub cover to 10 m high and chokes out the native species. Grazing by domestic stock and rabbits has also prevented seedling growth of many of the native species. Table 9 lists the plant species recorded by Woolls in 1867 and shows those still present in 1976, when the area was visited by the author. Such a group of species, most of which are normally restricted to rainforest, is unusual. A number are particularly rare; *Cynanchum elegans* (Asclepiadaceae), apart from the record by Woolls (it was not recorded in 1976) is known only from a few rainforest remnants near Wollongong

Table 9. Species recorded from the 'Native Vineyard' at Cobbitty by William Woolls (1867). (a, indicates also recorded by D.H. Benson in 1976 and b, recorded by Marie Kennedy in 1991).

Small trees		
Citriobatus multiflorus	a	
Geijera latifolia	a	b
Alectryon subcinereus	a	
Guioa semiglauca		
Alphitonia excelsa		
Diospyros australis		
Streblus brunonianus	a	b
Maclura cochinchinensis	a	b
Croton verreauxii		
Claoxylon australe		
Coelebogyne ilicifolia		
Euodia micrococca	b	

Vines		
Aphanopetalum resinosum	a	
Pandorea pandorana	a	b
Cissus antarctica	a	b
Eustrephus latifolius	a	
Geitonoplesium cymosum	a	
Sicyos australis	b	
Clematis aristata		
Passiflora herbertiana		
Stephania japonica		
Sarcopetalum harveyanum	b	
Cynanchum elegans		
Marsdenia flavescens	a	b
Parsonsia straminea		
Leichhardtia leptophylla		
Convolvulaceae (2 species)		

and scree slopes of Mount Dangar in the Hunter Valley. Similarly the nearest localities to the Native Vineyard for *Geijera latifolia* (Rutaceae) are Albion Park to the south and Pokolbin to the North. Similar vegetation is associated with the more rugged escarpments of Razorback Range between Camden and Picton on outcrops of the sandstone strata of the Bringelly Shale, particularly the Razorback and Mount Hercules Sandstone Members along gullies and cliff lines on sheltered northeast to southeast aspects. Phillips (1947) described a *Brachychiton-Bursaria* shrub stratum group found on outcrops of ostracod sandstone (possibly the Potts Hill Sandstone Member of the Minchinbury Sandstone). At the time these areas were mostly cleared and cultivated with only isolated specimens of *Brachychiton populneus*. Since then most of these have disappeared but it is probable that their original vegetation included 'rainforest type' shrubs.

Very little is known about the local ecological relationships between the three species *Eucalyptus moluccana*, *E. tereticornis* and *E. crebra*. *Eucalyptus tereticornis* may be found on more poorly drained sites than the others, though it also occurs on well-drained hill tops. *E. crebra* is found on dry hilly country, but often interspersed with the other species. It is probably slower growing than the other species. Locally pure populations of any of the species may be found, often in close proximity, suggesting different recruitment requirements may be involved. Past management practices such as the selective cutting of *E. crebra* for fence posts etc. may have led to local loss of this species.

Map unit 14a - Castlereagh Scribbly Gum Woodland

Low woodland: *Eucalyptus sclerophylla - Angophora bakeri*

This unit and the following map units 14b and 14c are part of the Castlereagh Woodlands of Benson & Howell (1990*a*), the characteristic vegetation of the Tertiary alluvial deposits of western Sydney with a very rich but poorly conserved flora.

Low woodland is found on sandy soils of the Tertiary alluvium around Castlereagh-Londonderry and at Holsworthy. It ranges from low woodland to woodland structure, with estimated canopy height ranging from 8 to 12 m. Projected foliage cover ranges from 20–32%. This structure probably approaches the original pre-settlement structure as neither of the main tree species has been cut to any great extent. This is also indicated by the mean basal area for the community (15.4 m^2/ha) (Table 10), which is much higher than the *E. fibrosa* open-forest 11.5 m^2/ha), a community that has been heavily logged. Fire, however, appears to have been frequent in recent times and may have increased the proportion of multi-stemmed plants. The understorey is variable, a 2 m high shrub layer being present at some sites but being replaced by sedges or grassed under conditions of poor drainage or frequent burning.

Eucalyptus sclerophylla, Scribbly Gum, is the most distinctive tree species, occurring as large spreading trees 8 to 12 m high. The most common species, however, is *Angophora bakeri*, generally a small tree with characteristically twisted branches. This species makes up to 70% of the basal area and 82% of stem density compared with 13% basal area and 6% stem density for *E. sclerophylla* (Table 10). Other tree species which may be present are *E. fibrosa*, *E. gummifera*, *E. eugenioides*, and in places with poorer drainage *E. parramattensis* subsp. *parramattensis*, *E. sideroxylon* and *Melaleuca decora*. A small group of *E. eximia* trees were found at the southern end of Castlereagh State Forest and may be a chance colonisation from the lower Blue Mountains. *Angophora bakeri* seems to be very tolerant of a wide range of drainage conditions and is equally common with *E. sclerophylla* on well drained sites, and *E. parramattensis* on poorly-drained ones.

Table 10. Basal area and density of major tree species from 6 sites in Castlereagh Scribbly Gum Woodland.

	Basal area (m^2/ha)			Density (plants/ha)		
	mean	(± s.e.m.)	% of total area	mean	(± s.e.m.)	% of total density
Angophora bakeri	10.84	2.0	70	496	139	82
Eucalyptus sclerophylla	2.06	1.4	13	38	17	6
Total	15.42	1.7		604	132	

Other species contributing to total basal area are *Eucalyptus fibrosa*, *E. gummifera*, *E. parramattensis* subsp. *parramattensis* and *Melaleuca decora*.

The understorey is of sclerophyllous shrubs. These may form a continuous cover or be more open, with grasses in between. Common shrub species are *Banksia spinulosa* var *spinulosa*, *Grevillea mucronulata*, *Hakea sericea*, *Leptospermum trinervium* and *Melaleuca nodosa*. At least two nationally rare shrub species endemic to the Tertiary alluvium of western Sydney, *Micromyrtus minutiflora* and *Persoonia nutans*, are found in this community. Recently a new species of *Allocasuarina*, *Allocasuarina glareicola* was discovered and described in Castlereagh State Forest in this community. There are only two small populations so far known.

The more open communities often result from frequent burning which favours the grasses and sedges at the expense of the shrub species. Common species are *Themeda australis*, *Eragrostis brownii*, *Patersonia sericea* and *Cyathochaeta diandra*. At certain times in the year ground orchids may be conspicuous.

This community usually grades gently into the adjacent *E. fibrosa* open-forest or *E. parramattensis* subsp. *parramattensis* low woodland. Where it adjoins communities on Wianamatta Shale the transition may be much more abrupt.

Soils on sites occupied by Scribbly Gum Woodland are very poor and until recently this community remained essentially undisturbed. However, extensive extraction of sand and gravel is now resulting in the removal of much vegetation, whilst the subdivision of much of the remainder into small holdings for suburban development, hobby farms, poultry farms etc. is also decreasing its extent. No examples have been reserved by the National Parks and Wildlife Service though proposals to make Castlereagh State Forest a Nature Reserve or Flora Reserve would ensure good conservation of this community. In general the future for the community appears to be poor. Hobby farm development results in the removal of understorey species and their replacement with exotic grasses, whilst council reserves are generally mown with similar results. The latter is regrettable for with care such remnants could be preserved in many areas as local examples of the original vegetation.

As far as disturbance, viability and management are concerned, similar comments to the Castlereagh Ironbark Forest, apply to this community. It is a well-drained community, on a nutrient poor soil which acts as a buffer to exotic weed invasion. Only three exotic species were recorded in this survey. The apparent uselessness of this soil type for agriculture and the unspectacular nature of the flat terrain make it appear as 'useless scrub', but if efforts are made to retain small stands in reserves etc., the richness and nature of the species in them could be successfully conserved.

Map Unit 14b - Agnes Banks Woodland

Low woodland/open-scrub: *Eucalyptus sclerophylla - Angophora bakeri - Banksia serrata.*

At Agnes Banks, south-west of Richmond, is a deposit of windblown sand of Pliocene-Pleistocene Age (Gobert, 1978) that supports an interesting shrub-dominated community, floristically similar to that found on coastal sand dunes such as those near Myall Lakes.

Soil depth varies from very thin at the edges, where the sands overlie the clay soils of the underlying Tertiary alluvium, to up to 7 m thick at the dune crests. On crests and ridges a 'coffee-rock' pan (<5 cm thick) occurs about 80 cm below the surface. On footslopes and in swales this pan is missing or may be discontinuous (Bannerman & Hazelton 1990). This pan may direct water into the swales increasing the differences in moisture between crests and swales. The relationship of vegetation to drainage conditions and the effects of a perched water table above a 'coffee-rock' horizon are shown in Figure 5.

Community structure is predominantly woodland to low woodland, but ranges from low open-forest to sedgeland. The characteristic tree species on well-drained sites are *E. sclerophylla* and *Angophora bakeri* and on poorly-drained sites *E. parramattensis. Banksia serrata* is generally a smaller but very distinctive tree species. Benson (1981) describes the vegetation in terms of five plant communities which occur in a sequence along a drainage gradient. These are:

a) **Low open-forest of *Banksia serrata* and *Angophora bakeri*.** A community apparently originally confined to the well-drained crests of the large dunes, most of which have been completely removed by sand extraction. The main trees are *Banksia serrata* and *Angophora bakeri*, up to 10 m high but the community may have occasional large, emergent trees of *Eucalyptus sclerophylla* up to 13 m. There is an open understorey of *Pteridium esculentum* and *Imperata cylindria* and scattered shrubs including *Ricinocarpos pinifolius, Eriostemon myoporoides* and *Bossiaea rhombifolia.*

b) **Woodland of *Eucalyptus sclerophylla, Angophora bakeri* and *Banksia serrata*.** This is the most widespread community, found on well-drained sites. It is dominated by trees of *Eucalyptus sclerophylla* 10 to 15 m high, together with smaller trees of *Angophora bakeri* and *Banksia serrata*. A large number of sclerophyllous shrub species is characteristic of the understorey, common species being *Leptospermum trinervium, Conospermum taxifolium, Ricinocarpos pinifolius* and *Isopogon anemonifolius.*

c) **Woodland of *Eucalyptus sclerophylla, E. parramattensis* subsp. *parramattensis* and *Banksia aemula* [previously *B. serratifolia*].** At the southern end of the sand deposit is woodland dominated by *Eucalyptus sclerophylla* but which appears to be restricted to shallower or less well-drained sand than Unit (b). Small trees of *E. parramattensis* up to 10 m high and large shrubs of *Banksia aemula* up to 7 m high are generally present. An understorey of sclerophyllous shrubs, similar to that in (b) above, is usually present. *Banksia aemula* may indicate more podsolised soils than Unit (b) with *B. serrata*, a situation reported for Myall Lakes (Myerscough & Carolin 1986).

d) **Low open-woodland of *Eucalyptus paramattensis* subsp. *parramattensis*.** This community is confined to poorly-drained situations. Small trees of *E. parramattensis* less than 10m high, either in clumps or as scattered individuals, are dominant though *E. sclerophylla* and *Angophora bakeri* may be present occasionally. The understorey is dominated by *Banksia oblongifolia*, which is in the most low-lying sites form a low shrubland, devoid of trees. Large tussocks of sedges and rushes are common. One sedge species, *Restio pallens*, common on the north coast of NSW and in southern Queensland reaches its southern limit at Agnes Banks.

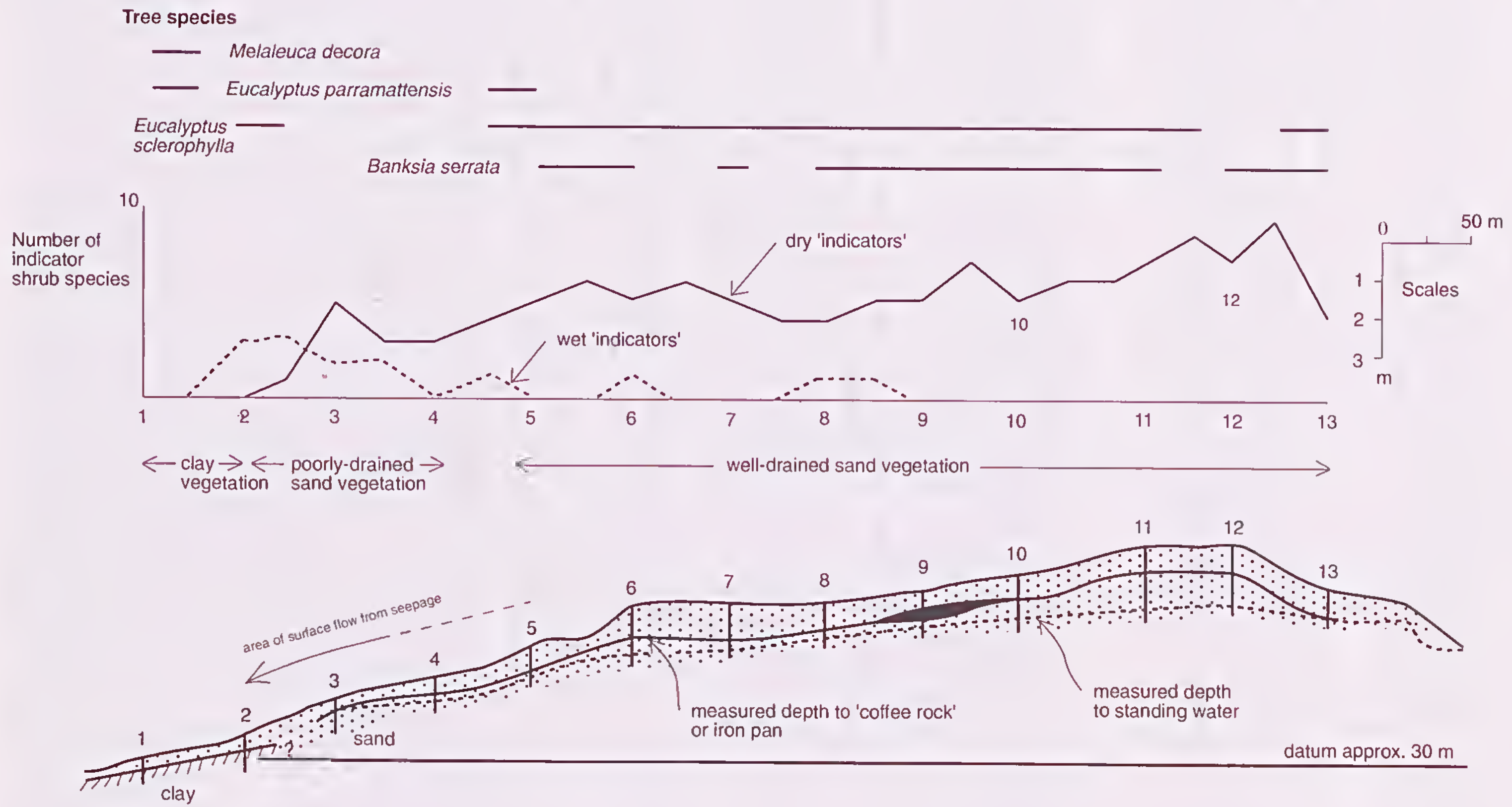

Tree species
Melaleuca decora
Eucalyptus parramattensis
Eucalyptus sclerophylla
Banksia serrata
10
Number of indicator shrub species
dry 'indicators'
wet 'indicators'
10
12
1
2
3
4
5
6
7
8
9
10
11
12
13
clay vegetation
poorly-drained sand vegetation
well-drained sand vegetation
0
50 m
1
2
3
m
Scales
area of surface flow from seepage
1
2
3
4
5
6
7
8
9
10
11
12
13
sand
clay
measured depth to 'coffee rock' or iron pan
measured depth to standing water
datum approx. 30 m

Figure 5. Occurrence of characteristic species along transect across sand dune at Agnes Banks showing relationship between topography and depth of iron pan. 'Wet' and 'dry' indicator species are those known from previous experience to be confined to particular moisture conditions.

e) **Sedgeland of *Lepidosperma longitudinale*,** with the small shrub *Melaleuca thymifolia*, occurs in a limited area in depressions between the main dunes where drainage is severely impeded. This vegetation has now been completely destroyed by mining and *Lepidosperma longitudinale* no longer occurs in western Sydney.

The vegetation on the sand deposit contrasts markedly with the surrounding vegetation and the boundary between the sand and the clay soils of the Tertiary alluvial deposits is very distinct. On the clay the dominant tree species becomes *Eucalyptus fibrosa* and the rich shrub understorey is replaced by a more open one predominantly of *Melaleuca decora* and *Bursaria spinosa* with a dense ground cover of grasses.

Part of this community is conserved by the Agnes Banks Nature Reserve but the area represented, 16 ha, is inadequate. Because it is on the shallowest sand, it preserves only a limited number of the characteristic species of the sand, and does not include examples of the low open-forest of *Banksia serrata - Angophora bakeri*, or the sedgeland of *Lepidosperma longitudinale*, or very much of the woodland of *E. sclerophylla - Angophora bakeri - Banksia serrata*. A Commission of Inquiry (Cleland 1988) found a further adjoining area to the north, to be of significance and a Permanent Conservation Order was recommended and later imposed by the Minister. The remaining sand area is proposed to be mined for construction sand.

Map unit 14c - Swamp Woodland

Low woodland: *Eucalyptus parramattensis* subsp. *parramattensis* - *Melaleuca decora*

Along creeklines, particularly Rickabys Creek, and in poorly-drained depressions on Tertiary alluvium near Castlereagh and Londonderry, is low woodland of *Eucalyptus parramattensis* subsp. *parramattensis* and *Melaleuca decora*. Occasional tree species include *Eucalyptus sideroxylon* and *E. sclerophylla*. Tree height at recorded sites ranged from 8 to 12 m and projected foliage cover from 8 to 18%. Basal area and plant density are much lower than the associated Castlereagh Ironbark and Scribbly Gum woodland (Table 11), but are probably indicative of the original structure, as the community has suffered little disturbance because of the poor agricultural soil and poorly-drained sites where it occurs. The main tree species, *E. parramatteusis* subsp. *parramattensis* makes up about 31% of basal area and 44% of plant density (Table 11). Stem diameters are generally small and almost always less than 25 cm d.b.h. The associated tree species *Melaleuca decora* and *E. sclerophylla* may both have larger stem

Table 11. Basal area and density of major tree species from 3 sites in *Eucalyptus parramattensis* subsp. *parramattensis* low woodland.

	Basal area (m²/ha)			Density (plants/ha)		
	mean	(± s.e.m.)	% of total area	mean	(± s.e.m.)	% of total density
Eucalyptus parramattensis	1.96	0.8	31	166	74	44
Melaleuca decora	1.76	1.7	28	83	71	22
E. sclerophylla	1.20	0.6	19	75	43	20
Total	6.39	0.7		375	80	

Other species contributing to total basal area are the tree *Eucalyptus sideroxylon* and the small tree *Angophora bakeri*.

diameters, though *E. sclerophylla* is generally a smaller tree than where it is found in Scribbly Gum Woodland.

The understorey is grassy and herbaceous with many annual or ephemeral species which respond to wet conditions. Density varies with the frequency and period since the last fire. The shrub layer may be mid-dense to open. Common species are *Banksia oblongifolia, Kunzea capitata, Hakea sericea* and *Melaleuca thymifolia*. The ground cover may be grassy and herbaceous or up to 60% bare. Common ground species are *Themeda australis, Imperata cylindrica, Dianella revoluta* and *Lepyrodia* species. Many species are annual or perennial and respond to wet conditions. These include *Isotoma fluviatilis* subsp. *fluviatilis, Gratiola pedunculata, Elatine gratioloides, Nymphoides geminata, Haloragis heterophylla, Lythrum hyssopifolia* and *Boronia polygalifolia*. Other species are particularly conspicuous after fire including *Ptilanthelium deustum* and terrestrial orchids including *Caladenia caerulea, C. carnea, Diuris maculata* and *Lyperanthus suaveolens*.

Depending on drainage Swamp Woodland may grade either gradually or abruptly into the associated Scribbly Gum Woodland (community 14a).

Many of the swamp woodland species have narrow habitat requirements and although widespread in distribution, are now rare or vulnerable because of loss of habitat, particularly on the Cumberland Plain, where most creeks and wet areas have been severely disturbed. For many of these species at least over half of herbarium collection sites on the Central Coast botanical subdivision are now likely to have been destroyed. One species *Hypsela sessiliflora*, originally collected from wet sites on the western Cumberland Plain has now been declared extinct (Briggs & Leigh 1988).

Swamp Woodland is potentially viable in the long-term. Because of the low nutrient status and poor agricultural value, it has remained essentially undisturbed, the low nutrient status and somewhat sandy nature of the soil being a buffer to exotic weed invasion except perhaps for *Andropogon virginicus*. Its poor drainage and occurrence in depressions and drainage channels, however, makes it susceptible to nutrient inflow and sedimentation, both of which facilitate weed invasion. Furthermore, it is now threatened by extensive clay-shale extraction proposals and hobby farm and suburban subdivision. No examples of this community have been reserved by the National Parks and Wildlife Service though a proposal to enlarge Agnes Banks Nature Reserve to the south, thereby including a good example of this community is now being considered. Castlereagh State Forest also includes some areas of this community.

Map unit 21f - Lower Blue Mountains Heath

Open-heath: ***Eucalyptus stricta - Allocasuarina nana***

Open-scrub: ***Angophora hispida***

Open-heath and open-scrub form part of the Sydney Sandstone Complex (in particular part of the Sydney Sandstone Ridgetop Woodland map unit 10ar). Open-heath is extensive enough to be mapped separately south of Woodford. Here it occurs on a series of rocky ridgetops along the Woodford Range. Characteristic species are the mallees of *Eucalyptus stricta* which here may have intergrading characteristics with *E. apiculata*, also *E. multicaulis, E. consideniana* and *E. oblonga*. A variety of shrub species is common including *Banksia ericifolia, Dillwynia floribunda* and *Petrophile pulchella*, together with ground species including *Lepidosperma flexuosum, Schoenus villosus, Restio fastigiatus, Patersonia glabrata* and *Lepyrodia scariosa*. *Allocasuarina distyla* is generally more common than *Allocasuarina nana*.

Small patches of open-scrub with *Angophora hispida* are found around Annangrove and Maroota, and in the former Maroota State Forest. Here rock platforms may have heathy 'islands' of shrubs growing in shallow soil in hollows in the rock. A rare shrub species endemic to those sites in the Maroota area is *Kunzea rupestris*. Characteristic species of these sites include *Calytrix tetragona, Dillwynia floribunda, Grevillea buxifolia, Petrophile pulchella* and *Platysace ericoides*. This vegetation probably represents a lower rainfall variant (annual rainfall about 800 mm) of the more coastal sandstone heath (annual rainfall 1 000-1 200 mm) found in Ku-ring-gai Chase and Marra Marra National Parks, rather than being Lower Blue Mountains Heath. Such areas are too small to show on the Penrith Map.

Map unit 26a - Blue Mountains Sedge Swamps

Closed-sedgeland: ***Gymnoschoenus sphaerocephalus - Lepidosperma limicola - Xyris ustulata - Baeckea linifolia***

This community, part of the Hawkesbury Sandstone Complex, is restricted to a number of poorly-drained sites on the Hawkesbury Sandstone plateau north of Springwood. These are generally related to impervious shale strata which collect the water and direct it out along springs and soaks which often follow topographic contours. Floristic composition is related to moisture availability and sediment depth. With deep sediment and permanent moisture the characteristic species are *Gymnoschoenus sphaerocephalus, Lepidosperma limicola, Xyris ustulata* and *Baeckea linifolia*. Where moisture is ephemeral, *Lepyrodia scariosa* predominates (Holland, Benson & McRae 1992). The main occurrence of sedge swamp however is in the higher Blue Mountains further west, from Wentworth Falls to Clarence where sedgeland and swamps are a characteristic feature of the landscape (Keith & Benson 1988).

Map unit 28a - Freshwater Wetlands

Open-sedgeland: ***Eleocharis sphacelata - Juncus usitatus - Persicaria* spp.**

Shrubland: ***Melaleuca linariifolia***

Freshwater wetland and swamp communities were once a feature of the Nepean–Hawkesbury floodplain. In the lower Hawkesbury between Pitt Town and Wisemans Ferry, these wetlands or 'backswamps' form in the depression between the levee bank along the River edge and the sandstone hillsides of the main river valley. Below Wisemans Ferry, wetlands are estuarine and influenced by salinity (see map unit 4a). Upstream of Pitt Town wetlands are less frequent and occur as depressions on the river floodplain. Most have now been cleared or drained. Indeed remnant wetlands vary considerably in terms of floristic composition, drainage and flooding conditions and water quality, and it is difficult to generalise on wetland behaviour.

Zonation patterns may be recognised in particular wetlands and related broadly to differences in water depths and periods of inundation. Floodplain wetlands may have areas that are permanently wet, semi-permanent with water present most of the year, or seasonal, which are dry for the greater part of the year depending on local rainfall conditions. Permanent and semi-permanent wetlands may have emergent reedland of *Eleocharis sphacelata*, which may grow to 1–2 m above the water level. *Typha* spp. may indicate higher-nutrient conditions or brackish water. Common smaller species are *Ludwigia peploides* subsp. *montevidensis, Triglochin procera, Myriophyllum* spp. and *Philydrum lanuginosum*. Death of above-ground vegetation during winter may result from severe frosts. Permanent wetlands often have extensive areas of open water sometimes with floating or submerged vegetation, depending on water depth or seasonal conditions.

Seasonal wetland zones do not usually have standing water, except following rain or during flooding, but the soil is often waterlogged or very moist. They may have rushland with tussocks of *Juncus usitatus* or herbland with scrambling *Persicaria* spp. (*P. decipiens, P. hydropiper, P. lapathifolia, P. praetermissa*). Less common are *Myriophyllum, Marsilea* and *Ranunculus* spp. There may be scattered individual shrubs where stock grazing has prevented regrowth or tall shrubland with *Melaleuca linariifolia, M. styphelioides* or *Casuarina glauca*. Depending on the topography the tall shrubland may grade into *Eucalyptus robusta* swamp woodland or, more commonly give way to *E. amplifolia* subsp. *amplifolia* - *Angophora subvelutina* River-flat Forest or Grey Box Woodland. In general the forest or woodland near wetlands has been cleared.

Remaining floodplain wetlands are concentrated in the area between Richmond and Sackville. Adam & Stricker (1989) record 25 floodplain wetlands for the 1:25 000 Wilberforce map sheet area that covers this area. These cover about 860 ha or over 80% of the total area of remaining floodplain wetland for the Penrith map sheet area (Figure 6). Sites with high conservation capability ratings include Wheeny Lagoon, Broadwater/Little Cattai Creek, Portland Head Farm, Reedy Swamp, Hawkesbury Campus of the University of Western Sydney and Castlereagh State Forest.

By their nature, many wetlands are narrow strips too small to show at the 1:100 000 scale of the Penrith map. Their absence does not indicate lack of importance, merely

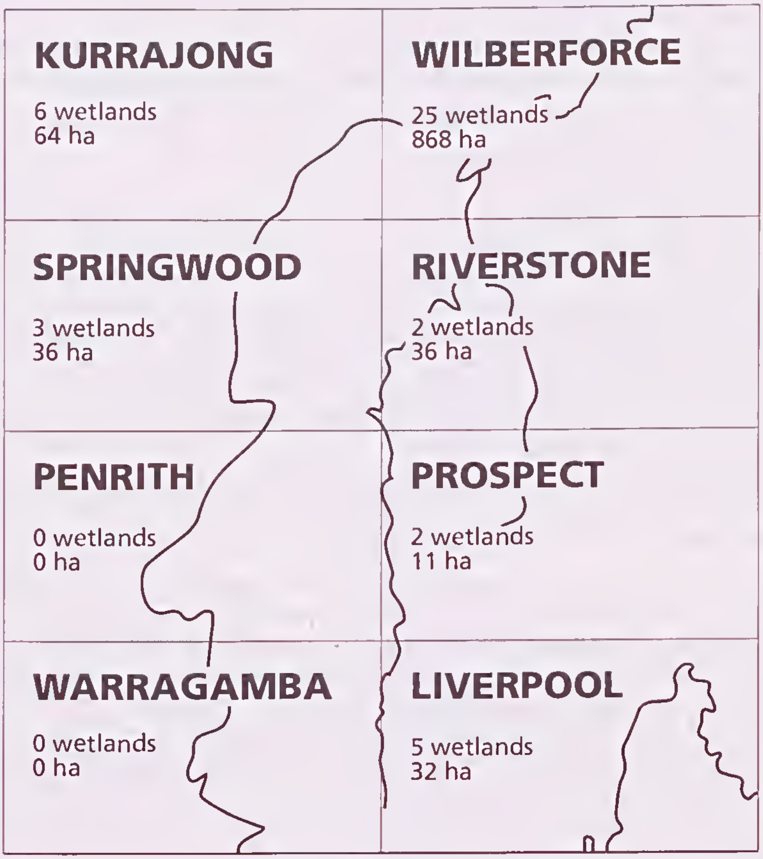


Figure 6. Area (ha) and number of floodplain wetlands within 1:25 000 map areas of the Penrith sheet. Data from Adam & Stricker (1989).

technical limits to their representation. Examples are Reedy Swamp in Mitchell Park, Pughs Lagoon near Richmond, backswamps between Yarramundi and Lowlands and at McGraths Hill.Though much freshwater swamp has been drained and replaced with improved pasture, indications of the original swamp vegetation may remain. *Juncus* spp. particularly *J. usitatus*, are of low palatability to stock and may persist.

Floodplain wetlands on the Georges River include Horseshoe Pond, New Brighton, Deepwater Park, Stockade Reach and Voyager Point. Voyager Point has an extensive wetland in very good condition. It is cut off from the Georges River by a levee bank and consequently fresh, rather than estuarine. In its upper parts the vegetation is low woodland and scrub with shrubs of *Melaleuca nodosa* and small trees of *Eucalyptus parramattensis* subsp. *parramattensis*. This is on very low nutrient soils derived from Tertiary alluvium. Further down tall shrubs of *Melaleuca ericifolia* and *M. decora* predominate, while at the northern end is an extensive area of sedgeland, with *Eleocharis sphacelata*, *Triglochin procera* and *Typha orientalis*. At the time of inspection there were extensive areas of open-water with a variety of small floating water plants such as *Myriophyllum*, *Utricularia* and *Nymphoides*. There is considerable fluctuation in the water level over the seasons. For example in August 1986 there was very little water. The vegetation here is extremely good condition with healthy native vegetation and very few weeds.

Wetlands in the Lower Blue Mountains are not floodplain wetlands but generally associated with deep sandy soils, very low nutrient status and impeded drainage. Burralow Swamp at Kurrajong on the margin of Blue Mountains National Park is an isolated wetland draining south to the Grose River. It is part of Burralow Swamp Soil Landscape (Bannerman & Hazelton 1990) and has a more sandy substrate than the floodplain wetlands, a very low fertility status (compared with the moderate fertility of the floodplain wetlands), very little standing water and a predominance of shrubs and ferns. Species include *Leptospermum polygalifolium*, *Hakea salicifolia*, *Hypolepis muelleri*, *Gleichenia dicarpa*, *Eleocharis sphacelata* and *Gahnia clarkei*. Other creeks in the Lower Blue Mountains, with deep sandy alluvium, such as Long Angle, Frasers and Fitzgeralds Creeks have similar vegetation often with *Melaleuca linariifolia* and forest of *Eucalyptus deanei*. Glenbrook Lagoon is a permanent open-water wetland of similarly low nutrient status with important sedgeland of *Lepironia articulata*, one of very few occurrences of this species in the Sydney area.

Seasonal wetlands have probably suffered the most from disturbance from draining, damming or grazing. Species in these sites probably depend on fluctuating water levels to promote growth and flowering. Alterations such as draining or damming stop seasonal levels from fluctuating and reduce sites for seasonal wetland species. Many of these are becoming rarer, but because we have limited data on their distributions, changes are difficult to quantify. At Longneck Lagoon, long term higher water levels and possible changes in water quality have occurred with a loss of wetland species and the growth of previously less common species.

Though there have been several general surveys of the extent of swamps along the Nepean–Hawkesbury system (Royal Botanic Gardens, 1986; Adam & Stricker 1989), there has been very little work on the plant ecology of the swamps themselves, despite the changes that are evident in lagoons like Longneck where past disturbance from stock grazing, draining and, most recently, partial damming by roadworks has altered the relative extent of vegetation zones and introduced a large number of exotic species. The task of separating the changes resulting from human activities - catchment disturbance and hydrological alterations - from climatically induced change, is difficult. However more information on these aspects is needed if adequate management of surviving wetlands is to be undertaken (Figure 7).

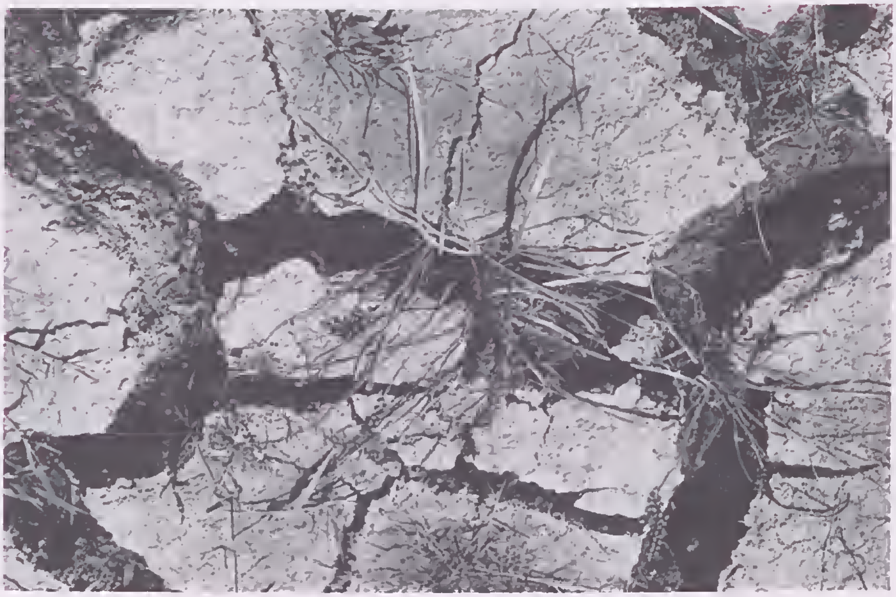


Figure 7. Floodplain wetland plants are adapted to fluctuating water levels; short periods of dryness can promote germination and establishment of new plants, such as *Triglochin procera* shown in mud cracks here at Reedy Swamp, Cattai, following a dry spring.

Cleared areas

Agricultural development and urban settlement have generally followed the more fertile soils of the alluvial flats and the Wianamatta Shale of the Cumberland Plain. The low nutrient soils of the Hawkesbury Sandstone and Tertiary alluvium have frequently survived with natural vegetation though extensive areas of Tertiary alluvium are now being cleared for extraction of sand and gravel. The major wildlife reserves are all on Hawkesbury Sandstone.

Discussion

Vegetation patterns

Vegetation patterns shown on the map sheet are limited by the scale of the final work. At 1:100 000 scale areas less than about 200 m across, for example, cannot be reproduced. Mapping conventions use lines to indicate boundaries, which may in reality be ecotones or gradations. Plant communities themselves may vary in composition in a much more complex way than can be indicated by assigning dominant species which may or may not be present at any particular place. The mapping units recognised here are subjective and result from observation and correlation of landform and floristic features. These correlations have not been experimentally confirmed though many of the patterns recognised have been proposed by earlier writers and confirmed by the extensive field observations of the present writer.

The close relationship between vegetation and geology in the Sydney area was recognised by the early explorers and settlers and used to assess potential land use (see earlier quotations). Many of their observations were confirmed later by scientists; Barwick (1903) and Carne (1908) describe the characteristic flora associated with volcanic necks. Cambage (1905) describes species restricted to areas of Narrabeen Group geology, and differences between the vegetation of the Wianamatta Shale and Hawkesbury Sandstone. Pidgeon (1937, 1941) described the major vegetation types confined to these geologies and Phillips (1947) discussed the differences between the vegetation on Wianamatta Shale, Tertiary alluvium and Holocene alluvium, respectively. Pidgeon described vegetation in terms of climax communities with the Precipitation/Evaporation index as a measure of the principal factor determining the distribution of vegetation. She stated that on shale the climate factor, and on sandstone the soil factor, is limiting. Phillips pointed out, however, that the soil and climate are interacting factors. Beadle (1962) demonstrated that nutrients, particularly soil phosphate are important in the distribution of vegetation types, and that the introduction of nutrients in the normally low nutrient soils both inhibits growth of native species and promotes the invasion of exotic weed species. Current thinking rejects the earlier concepts of climax communities (e.g. Clements 1936) and interprets vegetation patterns in terms of responses of species to variations in geology, soil texture and fertility, soil moisture relations and local climate.

That soil fertility alone is not a sufficient indicator of vegetation is shown in Table 12. Here soil fertility groups (in terms of chemical composition) as determined for the soil landscapes of Bannerman & Hazelton (1990) are related to vegetation. The findings follow the general trends with vegetation on volcanic soils being most mesic and the scleromorphic heaths being found on very low-nutrient soils. The Floodplain

Table 12. Soil fertility (from Bannerman & Hazelton 1990) for various plant communities.

Soil fertility	Plant community	Map code
Moderate:	Glen Forest	6c
	Freshwater Reed Swamps-floodplain wetlands only	28a
Moderate-low:	Spotted Gum Forest	9b
	Turpentine - Ironbark Forest	9o
	Grey Box Woodland	10c
	Grey Box - Ironbark Woodland	10d
Low:	Shale Cap Forest	9a
	Ironbark Forest	9c
	Shale/gravel Transition Forest	9d
	Castlereagh Ironbark Forest	9e
	River-flat Forest	9f
	Sydney Sandstone Gully Forest	10ag
	Castlereagh Scribbly Gum Woodland	14a
	Swamp Woodland	14c
Low-very low:	Camden White Gum Forest	6d
	Agnes Banks Woodland	14b
Very low:	Estuarine Complex	4a
	Sydney Sandstone Ridgetop Woodland	10ar
	Lower Blue Mountains Heath	21f
	Blue Mountains Sedge Swamps	26a
	Freshwater Reed Swamps-Lower Blue Mtns wetlands	28a

Forests, however, presumably with some of the biggest trees, and certainly the areas sought for cultivation by the early settlers, occurred on low nutrient soils according to Bannerman & Hazelton (1990). It would appear that soil texture, a permanent water supply and periodic flooding probably compensated for the low soil nutrients, which are indeed lower than for the nearby shale soils.

Regional affinities

The Penrith Map Sheet Area includes the largest areas of the Wianamatta Shale and Tertiary alluvial soils in the Sydney area. The Cumberland Plain Woodlands (Map Units 9b, 10c, 10d) are part of the Box Woodlands of the East and South-East described by Beadle (1981), in particular, part of his *Eucalyptus moluccana* Alliance. This occurs in rainshadows near the coast, e.g. the Cumberland Plain and the floors of the Hunter and Clarence River valleys, as well as patchily in the intervening areas, with outliers in the south, the drier parts of the Illawarra Plain, the Araluen and Bega valleys and a northern extension in small isolated stands as far as the Tropic of Capricorn. Beadle gives a number of grass and herb species for the Cumberland Plain and Hunter Valley though it is apparent that associated species are quite different as the Tropic is approached.

The Castlereagh Woodland is part of Beadle's Ironbark Forests and Woodlands of the East, and is referred to under his *Eucalyptus crebra* Suballiance, though the communities at Castlereagh contain more *Eucalyptus fibrosa* and even *E. sideroxylon* than *E. crebra*. The *E. crebra* Suballiance occurs throughout a large area of Queensland from north of the Tropic, through south-eastern Queensland onto the coastal lowlands of N.S.W. The communities form ecotonal associations with the low fertility coastal assemblages (i.e. the sandstone flora), according to Beadle.

Differences between shale, sandstone and alluvial floras have been recognised for many years, both in the observations of early settlers as they searched for indicators of better agricultural land, and in the work of Pidgeon, Phillips, Beadle etc. The distinctiveness of the flora on Tertiary alluvium was recognised by Phillips but only became more generally known in the 1970s. The need for representative areas of communities of soils other than sandstone is discussed in Benson & Howell (1990*a* & *b*).

Regional resemblances of the floras on the different soil types are interesting. During a study of the rare plants of Western Sydney, total floristic lists for the Cumberland Plains Woodland (439 species) and the Castlereagh Woodland (242 species) were compiled. Using distributional data from an updated version of Jacobs & Pickard (1981) we compared these floras with the total floras for the Botanical divisions and subdivisions of New South Wales (Table 13). We also compared the sandstone flora of Ku-ring-gai Chase National Park (313 species). The results show that whilst the flora of the Cumberland Plain Woodlands and the Castlereagh Woodlands has strongest resemblances with the Coastal subdivisions, nearly 75% of the Cumberland Plain flora also occur on the Western Slopes and nearly 45% on the Western Plains. The figures for the Castlereagh Woodlands are slightly lower at 66% and 37% respectively. This is much higher than for the Hawkesbury Sandstone flora, where only 34% of species occur on the Western Slopes and 10% on the Western Plains. It is also worth noting that, as well as having a similar floristic composition to the flora of the Cumberland Plain, that of the Western Slopes has been subjected to similar clearing and grazing pressures and is also poorly conserved (Figure 8).

In examining the current distribution of the vegetation it should also be borne in mind that species distributions have varied in response to fluctuating past climatic change. About 20 000 years ago, during the coldest part of the last of the Pleistocene

Table 13. Comparison of western Sydney flora with other botanical subdivisions of New South Wales.

Vegetation type*	No. of species	Percentage of species also occurring in				
		NC,SC	NT,CT,ST	WS	WP	FWP
Cumberland Plain Woodlands	439	94	87	74	44	17
Castlereagh Woodlands	242	92	87	66	37	10
River-Flat Forests	216	95	92	70	39	12
Hawkesbury Sandstone (Ku-ring-gai Chase NP)	313	85	81	34	10	2

*from Benson & Howell (1990a)
NC-North Coast, **SC**-South Coast
NT-Northern Tablelands, **CT**-Central Tablelands, **ST**-Southern Tablelands
WS-Western Slopes
WP-Western Plains
FWP-Far Western Plains

ice ages, the sea fell to its lowest level, 120–140 m below the present level (Benson & Howell 1990*a*). Given the close correlations of many species with climate today it is not unreasonable to speculate on vegetation patterns at this time. Many of the species on the Cumberland Plain are also found in the Tablelands and Slopes and are likely to have been able to cope with the colder and drier conditions. The Floodplain forests are likely to have migrated further down the Hawkesbury into the sheltered protection offered by the unflooded valleys of Broken Bay and Port Jackson. The coastal plain, beyond todays coastline, may have had sand dunes and alluvial soils perhaps with *Eucalyptus pilularis* - *Angophora costata* forests and associated vegetation similar to that found on the coastal lands at Myall Lakes. As sea level rose again to reach its present level about 6,000 years ago, it drowned the coastal river valleys of the Hawkesbury and formed the present floodplain. Coastal species including *Banksia aemula* and *Restio pallens*, another 'wallum' species, could have been dispersed inland to colonise suitable sandy substrates such as at Agnes Banks. A number of other Cumberland Plain species have disjunct coastal occurrences today - *Pimelea spicata, Thesium australe, Melaleuca nodosa* - possibly remnants of past migration patterns.

Such comments are speculative - more research into pollen studies, variation patterns within species and ecology and physiology is needed. However if we are to retain the raw material for these studies, conservation of adequate in situ populations across the area, not contaminated by genetic material transplanted from other areas, is necessary.

Rare or endangered species

A list of the native flora of western Sydney - covering most of the Penrith Sheet - has been recently prepared (Benson & McDougall 1991). This lists nearly 1 000 native species for the area with their conservation status. Many of these species are now very rare; 373 are regarded as vulnerable in a regional context. Of a list of 84 species, regarded as having particular conservation significance in western Sydney, 44% were

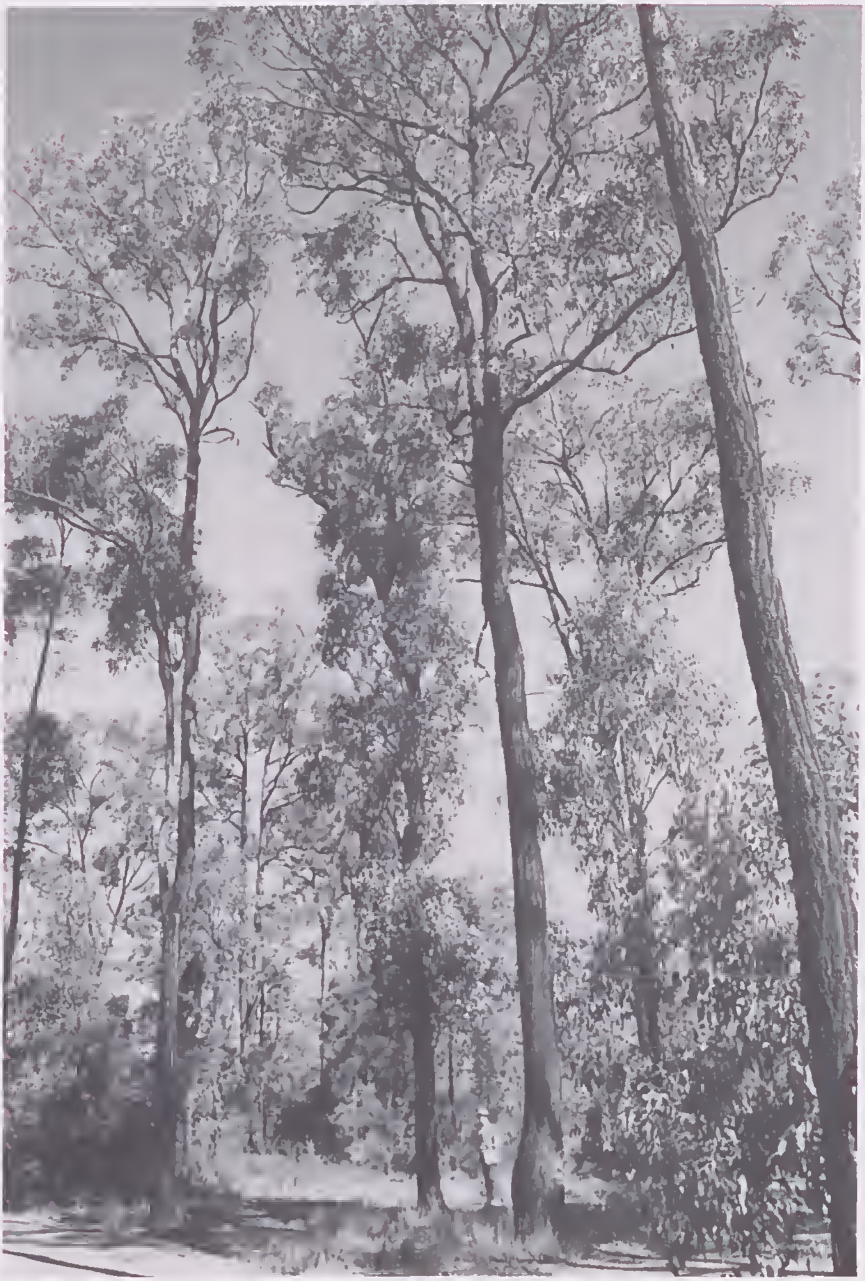


Figure 8. Some of the species found in the Castlereagh Woodland, such as the ironbarks *Eucalyptus fibrosa* and *Eucalyptus sideroxylon* also occur on the Western Slopes of New South Wales, under similar rainfall and soil conditions. Genetic differences between coast and inland populations provide potential scientific research material.

recorded in the Cumberland Plain Woodlands and 36% in the River-flat Forests (including freshwater wetlands), highlighting the need for better conservation of remnants of these vegetation types. Species of particular conservation significance within the Lower Blue Mountains region (not covered by Benson & McDougall) are given in Table 14.

At the very least, conservation plans for all those on the national list (Briggs & Leigh 1988) such as *Pultenaea parviflora, Micromyrtus minutiflora, Persoonia nutans, Acacia pubescens* (the largest remaining population, at Prestons, is currently threatened) and *Pimelea spicata* should be carried out urgently.

Conservation of vegetation

Long-term conservation strategies to conserve and enhance natural vegetation in the Penrith sheet area are needed. These should include:

1. Protection of major reserves and their catchments

Table 15 and Figure 9 show the conservation reserves for plant communities on the Penrith Sheet. Though large areas of sandstone country on the Lower Blue Mountains are protected, it is clear that conservation of the western Sydney vegetation, and in particular the Cumberland Plain and Castlereagh Woodlands is inadequate. Conservation of these areas has been actively sought since the early 1970s, but increasing land prices and the tendency to put off difficult land use decisions, has impeded progress. Recommended major conservation areas given in Benson & Howell (1990*a*) are:

- The catchment of Longneck Lagoon which includes important areas of Grey Box woodland and protects the catchment of this important wetland;
- The southern additions to Agnes Banks Nature Reserve; these would protect significant areas of Castlereagh Woodland on poorly drained sites;
- Castlereagh State Forest, which needs permanent protection as a flora reserve for its important ironbark forests and diverse flora;
- Commonwealth land at Shanes Park, which should be acquired to protect intergrading vegetation on shale and Tertiary alluvium;
- The Mulgoa Nature Reserve proposal with its interesting shale cliff-line habitat;
- The Kemps Creek Nature Reserve proposal, which should be established to protect low-lying Cumberland Plain Woodland;
- Water Board land around Prospect Reservoir, needing permanent protection for its important woodlands.

To date (February 1992) none of these areas have been formally protected.

2. Identification and protection of small remnants

Much of the long-term conservation of the flora of western Sydney will depend on the conservation and management of small reserves by a number of different authorities including the N.S.W. National Parks and Wildlife Service, Forestry Commission, Water Board, and about 10 local councils. Success will be patchy and depend in the long term on availability and application of specific information on the nature of the particular reserve, together with a general increase in education in environmental management.

Table 14. Species of particular conservation importance within the Lower Blue Mountains region of the Penrith 1:100 000 map sheet. For significant species of the western Sydney and Cumberland Plain region, see Benson & McDougall (1991).

Species listed here are either rare or threatened (from Briggs & Leigh 1988) or of significance in terms of geographic distribution, or localised populations disjunct from other occurrences.

DICOTYLEDONS

CHLOANTHACEAE
Chloanthes glandulosa- Springwood to Kurrajong, main population, (one record for South Coast)

CUNONIACEAE
Acrophyllum australe- Woodford to Faulconbridge, 2VCi, local endemic

DILLENIACEAE
Hibbertia hermanniifolia- Bents Basin, Wallacia, 3RCa, disjunct local pop. Nth-limit

EPACRIDACEAE
Epacris sparsa- Avoca Vale, very rare local endemic
Leucopogon fletcheri- Springwood, Blaxlands Ridge, 3RC-, local pop.
Monotoca ledifolia- Sublime Point, Leura, 3RC-, locally restricted with small populations

MYRTACEAE
Eucalyptus benthamii- Nepean R. Wallacia- Camden, Kedumba Ck, 2VCi, local endemic
Eucalyptus burgessiana- Faulconbridge, Linden, 2RCa, local endemic
Leptospermum emarginatum- Nepean River, Penrith; Bents Basin, local pop. Nth-limit

PROTEACEAE
Grevillea longifolia- Lawson-Springwood, 2RC-, disjunct local pop.
Persoonia hirsuta- Springwood-Glenbrook, 3KCi, local pop.

RUBIACEAE
Canthium coprosmoides- Avoca Vale, local pop.
Psychotria loniceroides- Avoca Vale, local pop.

RUTACEAE
Zieria involucrata- Springwood, Burralow Swamp, 2VC-
Zieria murphyi- Tomah Saddle, 2VC-

SOLANACEAE
Cyphanthera scabrella- Glenbrook Gorge, Erskine Ck, Bowen Ck, 2RC-, restricted local endemic

TREMANDRACEAE
Tetratheca neglecta- Yerranderie, 2RC-

MONOCOTYLEDONS

CYPERACEAE
Carex neurochlamys- Avoca Vale local pop., Sth limit

IRIDACEAE
Libertia paniculata- Avoca Vale, local pop.

LOMANDRACEAE
Lomandra fluviatilis- Bents Basin, Nortons Basin, Glenbrook Creek, 3RC-

(pop = population, Sth - southern, Nth = northern; codings from Briggs & Leigh)

Table 15. Major conservation reserves in the area covered by the Penrith 1:100 000 map sheet.

Reserve	Approx area on map sheet (ha)
Agnes Banks Nature Reserve	64
Windsor Downs Nature Reserve	330
Bents Basin State Recreation Area	399
Georges River State Recreation Area	part only
Cattai (incl. Mitchell Park) State Recreation Area	116
Blue Mountains National Park	part only
Wollemi National Park	part only
Castlereagh State Forest (Demonstration Forest)	448

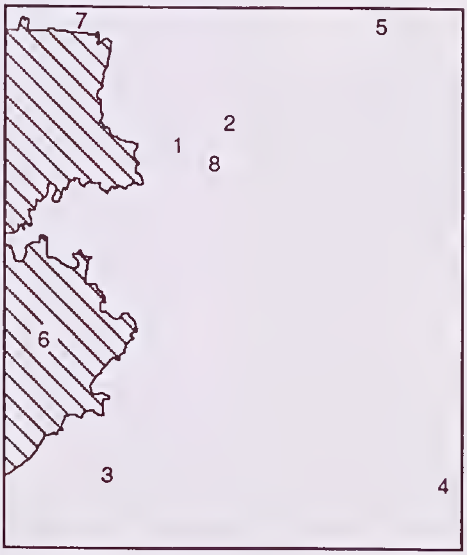


Figure 9. Location of conservation reserves for Penrith map sheet area. 1 Agnes Banks Nature Reserve; 2 Windsor Downs Nature Reserve; 3 Bents Basin State Recreation Area; 4 Georges River State Recreation Area; 5 Cattai State Recreation Area; 6 Blue Mountains National Park (hatched); 7 Wollemi National Park; 8 Castlereagh State Forest.

In particular, the importance of the role of local councils should not be overlooked. The now disparate occurrences of many of the plant species in western Sydney mean that many are not included within the National Parks and Wildlife Service reserves system and occur in small areas under council control (Figure 10).

Whereas local plant populations in the small reserves in the sandstone areas are generally backed up by larger populations in the surrounding National Parks, there are no large reserves for the Wianamatta Shale, Tertiary and Holocene alluvium plant communities of Western Sydney. The potential for future losses in reserves in these areas is therefore of far greater significance. Such areas will gradually become even more fragmented than they are now and the tendency to tidy up wild areas, using lawn mowers, herbicides, etc., along margins, fences, roads, paths, reduces irrevocably a little more of the natural diversity each time .

A long-term trend that should be recognised is the increasing amount and quality of run-off water being directed into remnant natural areas. The addition of nutrient and

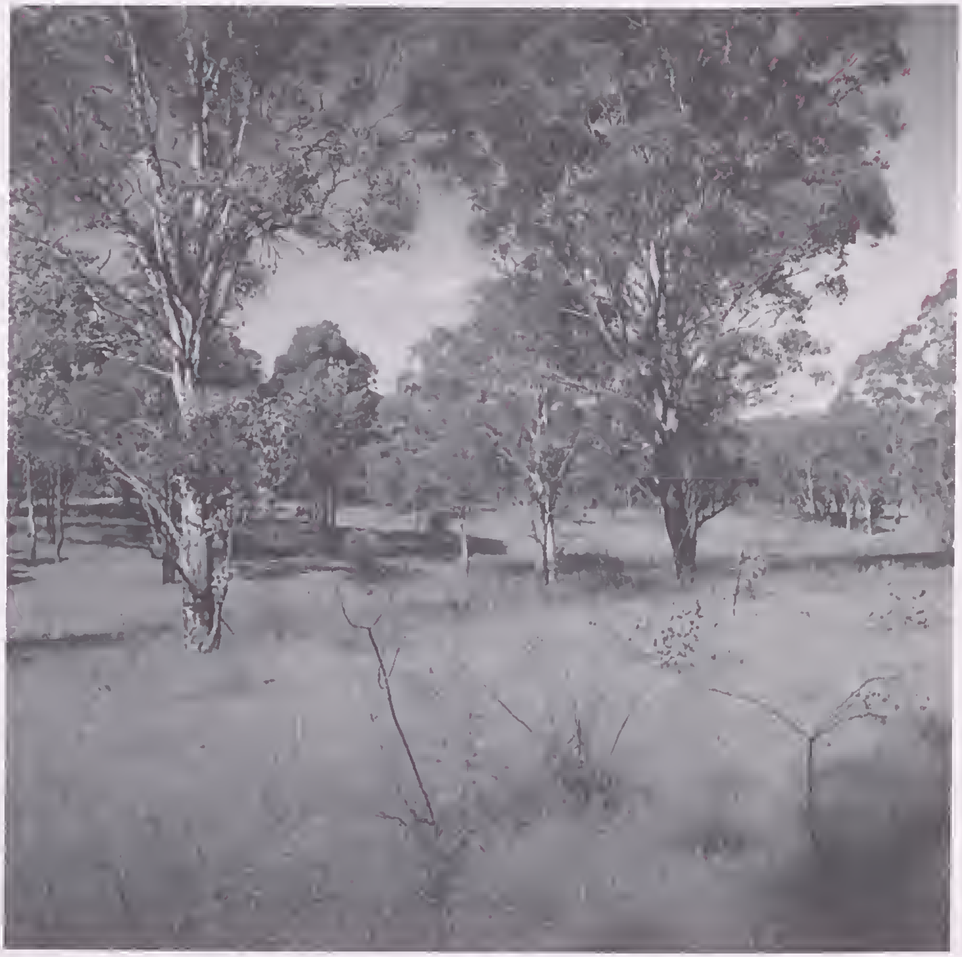


Figure 10. Lansdowne Park contains extensive areas of Cumberland Plain Woodland, many of the species of which respond well to periodic fires. Fortunately it is large enough to support a managed fire regime, despite its suburban context.

promotion of weed invasion is now widely recognised (e.g. Buchanan 1989) and threatens, in particular, the low-nutrient habitats. Increasing volumes with increased nutrients result from the large scale paving of hard surfaces in built-up areas, the loss of trees, the greater use of water in gardens, car washing, sewer discharges, pet excrement (pets may add 3–10 kg/ha/year of phosphorus to suburban areas - Benson & Howell 1990*b*), and the increasing concentration of run-off in fewer creek lines and channels. As discussed earlier, the Cumberland Plain vegetation is adapted to conditions of low rainfall and is therefore capable of sustaining periods of drought. Increased soil moisture, however, is more likely to eliminate native species by favouring rank growing exotic species. Apart from the well publicised dangers of Privet, *Ligustrum* spp. *Lantana camara*, *Tradescantia albiflora* etc., the spread of Kikuyu, *Pennisetum clandestinum*, is a danger. This grass is being used more frequently in recreation areas and disturbed sites and is a vigorous invader of native bush where the conditions are suitable.

3. Identification of corridors, regeneration and planting

Corridors linking the major conservation reserves and smaller remnants need to be designated and enhanced. The main north-south creek systems, Eastern Creek, South Creek and Kemps Creek, together with the Hawkesbury-Nepean and Georges Rivers should be the skeleton, together with interconnections across catchment divides. Some of these corridors, for example Eastern Creek, are already recognised by the Department of Planning, but plans for encouraging natural tree regeneration and planting need to be developed. Regeneration should be encouraged where residual native vegetation remains as this retains the scientific values of local genetic provenances. Any planting in a natural site should be propagated from local material.

4. Treatment of flood-prone areas and wetlands

Remnant vegetation often survives in floodprone areas. Wetlands, in particular, are important and should be protected from drainage or other alteration. Although such sites are not suitable for urban development, they are highly susceptible to changes and increasing volumes of run-off from adjacent urban areas. In some areas the increased run-off has led to the native creek vegetation being replaced by broad concrete stormwater channels. Since this creekside vegetation is often the only remaining vegetation, its destruction is a major loss of local biodiversity. There may also be cases where wetlands should be rehabilitated. Pitt Town Nature Reserve has been heavily grazed and most native species except for some *Juncus usitatus*, *Carex appressa*, *Triglochin procera* and *Persicaria lapathifolia* have gone. It is an important site for birds and provides scope for rehabilitation.

5. Identification of buffer zones

Because many of the conservation areas and bushland remnants are small and will soon be surrounded by increasingly dense urban populations, buffer zones will be needed and should be developed now. Such areas should be established with appropriate local native trees and shrubs to provide semi-natural bush to take intensive recreational use out of the intact bushland remnants.

6. Maintaining diversity of other wildlife, particularly birds and invertebrates

In areas planned for future urban development, tree planting, where it is appropriate, rather than preservation or regeneration, should be carried out in advance of building, since established trees will greatly enhance the new suburb's environment. Plantings need to recognise the needs of local fauna, particularly birds and invertebrates. Birds of the dry woodlands of western Sydney should be encouraged by planting woodland and forest groves, of local eucalypt species together with local understorey species including grasses and herbs. The use of non-local but colourful species such as grevilleas, whilst suitable for home gardens, should not be used in large-scale plantings as these favour the common garden birds, rather than providing suitable conditions for the specific local birds of western Sydney.

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The natural vegetation of the Balranald – Swan Hill area

J.A. Scott

Abstract

Scott, J.A. (National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, Australia 2000) 1992. The natural vegetation of the Balranald – Swan Hill area. Cunninghamia *2(4): 597–652.* The present-day natural and semi-natural vegetation of the Balranald and the Swan Hill (New South Wales section) 1:250 000 map sheets (south from 34°00′S to the Murray River; 142°30′E to 144°00′E) in semi-arid south western New South Wales is described and mapped. The area is part of the South Western Plains and South Far Western Plains botanical subdivisions. Twenty vegetation communities are recognised including mallee, woodlands of Belah-Rosewood (*Casuarina pauper-Alectryon oleifolius* subsp. *canescens*) and *Callitris*, riverine forest and various chenopod shrublands. Vegetation has been mapped using a combination of aerial photographs, field survey and LANDSAT imagery. The vegetation patterns reflect landform (an east-west transition from the fluvial and lacustrine plains to the aeolian sand dunes) and soil types (heavy clays of the plain to calcareous sands). All vegetation shows disturbance (grazing, clearing and cropping, erosion and weeds). Most plant communities are poorly conserved, with less than half of the communities represented in the 3% of the mapped area currently reserved.

Introduction

Location

The mapped area (south from 34°00′S to the Murray River, 142°30′ to 144°00′E) is located in the semi-arid zone of south-western New South Wales. It comprises the Balranald 1:250 000 map sheet (S1 54-12) and the New South Wales section of the Swan Hill 1:250 000 sheet (S1 54-16). This area adjoins the eastern edge of the Mildura sheet which was mapped as part of the Ana Branch - Mildura vegetation map (Fox 1991). This mapping is part of a major project of the Royal Botanic Gardens to map the vegetation of south-western New South Wales.

There are two main rivers in the area (Fig. 1). The Murray River flows from south-east to north-west, forming the southern boundary of New South Wales and of the mapped area. The Murrumbidgee River flows south-west joining the Murray approximately 35 km south-west of the town of Balranald. It also marks in part the boundary between the Central and Western Divisions of New South Wales. South-west of Balranald the division boundary leaves the river, passes through Kyalite, then down the Wakool River to its junction with the Murray River. The greater percentage of the mapped area falls within the Western Division under the tenure of the Western Lands leases.

The main towns are Balranald (population of 1 400) on the Murrumbidgee River and Euston (population of 400) on the Murray River. These towns are linked by the Sturt Highway which runs east-west from Wagga Wagga to South Australia. The main north-south road links Balranald to the Cobb Highway at Ivanhoe in the north. Swan

Hill is the largest centre in the area (population 9 500) located on the Victorian side of the Murray River. The area beyond these towns is sparsely settled. The map covers parts of four shires: Balranald, Wakool, the easternmost edge of Wentworth, and the westernmost edge of Hay. It covers sections of the botanical subdivisions of the South Far Western Plains and South Western Plains, the boundary between the two is through Balranald. The total area of the map sheet is approximately 17 000 km^2.

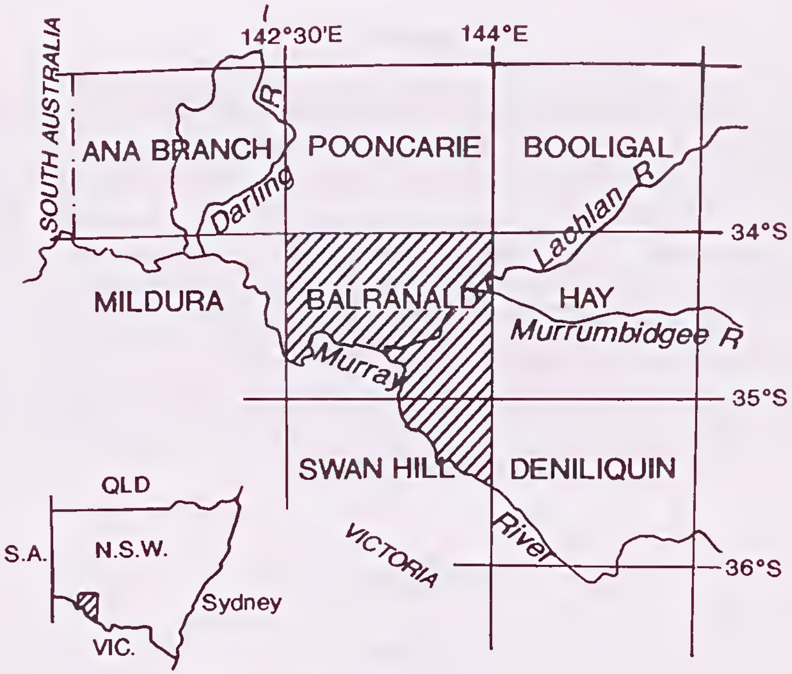

Figure 1. Locality map showing part of the 1:250 000 map grid.

Climate

The climate of the study area is semi-arid. Temperatures are hot in summer and mild in winter (Table 1). The hottest month is January with an average daily temperature range of 16–33°C; the coldest month is July with an average range of 3–16°C recorded at Balranald (Bureau of Meteorology, 1988).

Rainfall is low and highly variable. The mean yearly rainfall, based on 107 years of record, for Balranald is 320 mm, and gradually decreases to the north and west. The rainfall is relatively evenly distributed throughout the year, only slightly higher and more frequent in the winter/spring months of May to October. In the summer months there are occasional heavy rainfalls yielding the higher values for the mean compared to the median. The variation from year to year is high, for example 1973 had 692 mm whilst 1982 had 129 mm (Bureau of Meteorology 1988).

The high evaporation experienced during summer, greatly reduces the availability of moisture to plant growth. June to September is generally the most favourable period for plant growth (Rhodes 1990).

Table 1. Climatic averages for Balranald for temperature (20 years of record) and rainfall (107 years of record) (Bureau of Meteorology 1988).

	J	F	M	A	M	J	J	A	S	O	N	D
Daily Max. Temp. (°C)	32.6	32.5	29.0	24.2	19.5	16.1	15.8	17.5	20.1	23.9	27.4	30.5
Daily Min. Temp. (°C)	16.4	16.6	13.7	9.9	7.0	3.8	3.2	4.7	6.7	9.8	12.2	14.2
Rainfall (mm)												
Mean	21	24	24	24	32	30	25	30	29	32	26	23
Median	9	12	16	17	28	25	22	26	24	23	17	15
Rain days (Mean no.)	3	3	3	4	6	7	7	8	6	6	4	3

Geology and geomorphology

The mapped area falls within the Murray Geological Basin (Fig. 2), formed during the Tertiary period approximately 60 million years ago. The pre-Tertiary geology described in Pels (1969) and summarised in Fox (1991) indicates a long period of sedimentation underlying the basin. There are no rock outcrops within the mapped area unlike the edge of the basin in the Darnick and Manfred Ranges to the north-west.

Sedimentation in the Tertiary provided much of the source-material for the geomorphological processes in the Quaternary which shaped the landscape seen today. It also apparently controls some of the geomorphic features such as drainage and the presence of major aquifers (Soil Conservation Service 1990). Within the mapped area the landscape history can be best described in three sections according to the geomorphological processes responsible for their formation.

The western half of the Murray Basin encompassed the Murravian Gulf (Fig. 2) which was shaped and infilled largely with marine sediments in the late Tertiary. At its maximum (during Miocene time) the sea extended as far east as Balranald where marine sediments containing abundant fossils have been found at depths of 150–270 m (Pels 1969). Its regression left ridges of Parilla Sand (Firman as cited by Bowler & Magee 1978). Further sedimentation took place when most of this area was again inundated, this time with fresh water from the damming of the Murray River forming Lake Bungunnia. This drained out approximately 700 000 years ago (Bowler 1980). During the Quaternary the deposits were reworked by the wind into dunefields and sandplains of the Woorinen formation (Lawrence 1966). This aeolian landscape has its easternmost edge in a line approximately north-south through Balranald.

East of Balranald is the riverine plain. This is a fluviatile landscape deposited by the system of prior streams that eroded the Murrumbidgee and Lachlan valleys in the late Pliocene and Pleistocene times (Woolley 1978, Butler 1950). The present surface of the plain represents the final phase of prior stream deposition that took place in the Quaternary and is regarded as a relic landform of this age (Pels 1969). The raised stream beds and levee banks of the last of the prior stream channels can be seen on the plain today as slight sandy rises. They are more easily seen from the air. These rivers carried greater discharges than the present rivers, as evident from the greater channel width and longer meander wavelengths. Clays were deposited from the prior streams when water was isolated beyond its levees on extensive floodplains (Pels 1969). The present-day rivers, the Murrumbidgee, Lachlan and Murray which meander across the landscape, have not been responsible for the topography of the plain (Pels 1969).

The transition zone between these two distinctive landscapes, fluviatile in the east and aeolian to the west, runs through the centre of the mapped area (Fig. 3). It marks the transition from riverine sources of sediment from the east to the marine and littoral sources of sediments from the west (Mabbutt 1980). This boundary has fluctuated over time and is important in providing landform evidence of climatic change (Mabbutt 1980). The landforms are possibly of riverine or lacustrine origin with a veneer of aeolian material (Scriven 1988*b*). Fluviatile sediments are thin, and ancient lunettes formed in the Tertiary period are often exposed (Pels 1969). The two processes, aeolian and fluvial, have combined to produce lake basins that were active in a

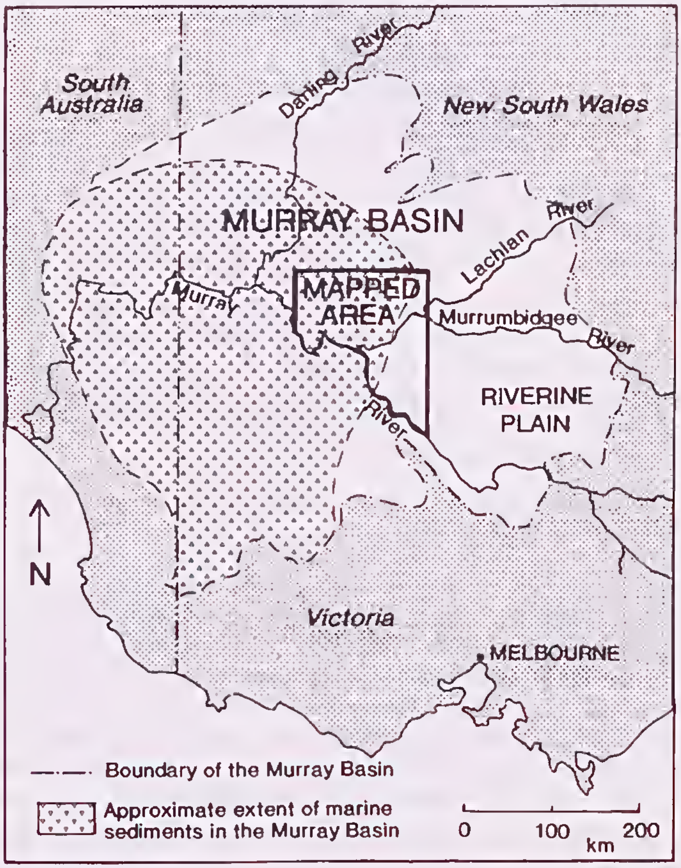

Figure 2. Map of south-eastern Australia showing the location of the mapped area within the Murray Basin. Based on a map by Lawrence (1966).

wet phase of the Pleistocene 50 000 to 25 000 years ago (Bowler & Magee 1978). A drying-out phase followed, with its peak in the last glacial period 18 000 to 16 000 years before present. During this time dune building occurred on the eastern edges of each lake, forming lunettes. These are still present today.

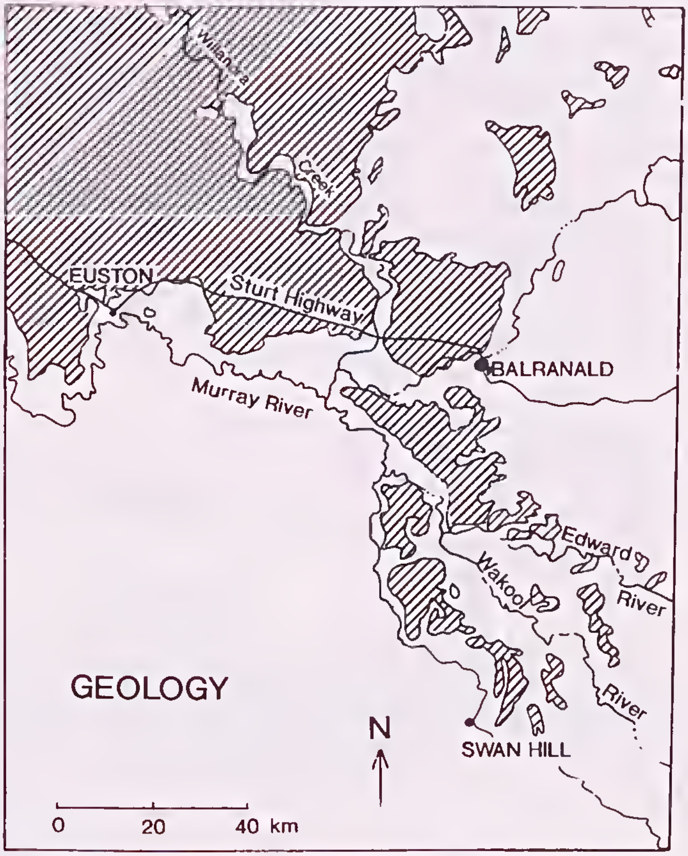

Figure 3. The geology of the mapped area based on a map by the Soil Conservation Service of New South Wales (1990). Hatched areas are largely aeolian, flat to gently undulating plains and dunes of red and red-brown clayey sands and loams. Unhatched areas are flat alluvial and lacustrine deposits of gravel, sand, silt and clay.

Present landforms

Rivers

The major rivers flowing through the area are the Murray and the Murrumbidgee, which enters the Murray 35 km south-west of Balranald. The Edward and Wakool Rivers, which branch near Deniliquin, flow to the west in parallel courses and reunite near Kyalite before entering the Murray just upstream from the Murrumbidgee. The rivers carry water from the tablelands and slopes in the east across the Riverine Plain where there is limited contribution from runoff. The Great Cumbung Swamp occurs on the Lachlan River just north of where it enters the Murrumbidgee on the easternmost side of the mapped area. It is one of the most significant inland wetlands in NSW (Pressey *et al.* 1984).

Dunefields

The linear dunes are relic features stabilised for the last 15 000 years by vegetative cover. They occur on the western half of the map-sheet area forming a series of parallel rounded ridges with a west-east orientation. These dunes vary in height from 2 m to 6 m from crest to swale, spaced with approximately 0.2–1.2 km between adjacent dune crests, and are commonly 0.5–1 km in length, sometimes to 3 km in the west. Their average composition is 7–10% clay content and 5% calcium carbonate, with the highest values in the swales and the lowest on the dune crests (Bowler & Magee 1978). The swales contain fine-grained clay loam, often with limestone nodules.

The dunefields are a part of the Woorinen Formation (Lawrence 1980), which extends into northern Victoria. The sand content of these dunes is thought to have originated from the Parilla sands deposited with the retreat of the Murravian Gulf in the upper Miocene to lower Pliocene (Bowler & Magee 1978, Lawrence 1980, Semple 1990). The clays are thought to have originated from the lacustrine sediments of the Quaternary, whilst the calcite from cyclic salts and as dust derived from shells exposed on the South Australian coastline at times of low sea level (Lawrence 1980). The dunes become less frequent in their distribution from west to east, becoming absent on the sandplains.

North of Lake Benanee lies a broad flattish NW-SE aligned area of non-linear sand dunes (Fig. 4). Similar ridges in south-west Victoria and South Australia are postulated to be relic Tertiary shoreline features formed by the retreat of the sea in the Late Tertiary (Bowler & Magee 1978, Blackburn 1962), depositing Parilla Sands (Macumber 1969, Bowler & Magee 1978, Lawrence 1980).

Sandplains

Sandplains occur in the middle of the map-sheet area where the aeolian sand cover is thinner, in the zone of transition between the dunefields to the west and the Riverine plain in the east. They support Mallee, and Belah-Rosewood woodland (*Casuarina pauper* with *Alectryon oleifolius* subsp. *canescens*). The land is flat and there are generally no dunes. The clay and calcium content is higher than in the dunes, but the origin of the sediments is similar.

Lakes

The numerous lakes in the area are relic features relating to hydrologic events of the late Pleistocene (Bowler & Magee 1978). They were full when the climate was wetter 50 000 to 25 000 years ago. At this time the lakes of the Willandra system to the north overflowed through an outlet channel, still evident today west of Balranald, to join the Murrumbidgee River. The Prungle Lakes are the southernmost of this system and part of the Willandra World Heritage area. The lakes nearer Balranald also date from this time; their water source was probably from an elevated water-table across the region (Pressey *et al.* 1984).

In appearance, the lakes are typically smooth and elliptical, often kidney-shaped in outline with the long axis oriented north-south. They vary in size from 2 km long (Moonlight Lake) to 10 km long (Pitarpunga Lake). Most lake basins are dry although some near the floodplains of the Murray and Murrumbidgee Rivers are intermittently filled when the rivers are flooded. Others are now artifically filled for use as water storage basins. The sediments on the lake floors consist of slightly saline calcareous clays, with silts and sands more prominent on the eastern downwind margins (Mabbutt *et al.* 1982).

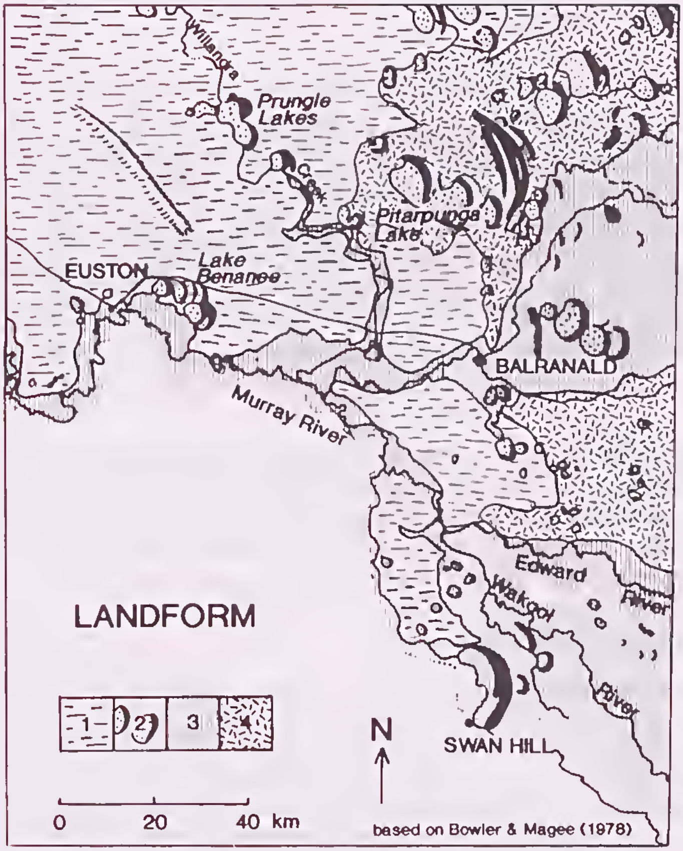

Figure 4. Landform features and geomorphology of the mapped area. Aeolian: 1. linear dunes and sand plain, 2. lunettes on eastern side of lakes. Fluvial: 3. low level alluvium, 4. clay plain. Based on a map by Bowler and Magee (1978).

Lunettes

Lunettes are the smooth cresent-shaped dunes on the eastern edge of the lakes. They are thought to be formed 40 000 to 15 000 years ago with the most intensive phase at the peak of the last glaciation 18 000 to 16 000 years before present (Bowler 1976). At this time the climate was drier and slightly cooler with temperatures several degrees below their present mean (Bowler 1980). The lunette building process occurred as a result of the seasonal flooding and drying out of the lake leaving a salt residue on the lake bed which helps break up the clay soil. The clay particles are then blown by unidirectional winds and deposited to form a dune (Bowler 1980). The resulting lunettes are composed predominantly of clayey sands, gypseous clays and, as in Prungle Lake, almost pure gypsum (Australian Heritage Commission 1980). The size of the lunette is proportional to the size of the lake.

Riverine plain

The western edge of the riverine plain covers the eastern quarter of the map sheet. The plain, consisting of Quaternary alluvium, is mostly treeless except for the forests and woodlands along the rivers, and the woodlands on the levees and raised beds of prior streams. The soils are mainly heavy clays and the dominant vegetation communities are chenopod shrublands.

Prior streams and source-bordering dunes

Prior streams (Butler 1950) were major river systems active in the Pleistocene which deposited sediment forming the present-day Riverine Plain. The stream traces, seen on the present landscape most clearly from the air, cross the plain and fragment as they near the transition zone on the western edge of the plain. They appear on the ground as a change to redder sandier soil and/or slight sandy rises, representing the old source-bordering dunes and raised stream bed. South-east of Balranald the remains of one such prior stream is seen as red sandy rises across the landscape with remnants of *Callitris* mixed woodland.

Soils

There is a high correlation between soil type and landform. The following soil descriptions have been taken from Charman and Murphy (1991), Northcote (1980) and from the soil map for Balranald (Eldridge 1985). Much of this area is covered in a fine-grained sediment known as parna, which covers the plain and swales of the dunefields (Butler 1956).

Plains of calcareous earths

The most extensive soil type is grey-brown loamy calcareous earths, often with exposed cemented carbonate at the surface. They are found between and to the north of Balranald and Euston. Isolated sandy dunes of low relief are associated with flats of various duplex soils. To the east of Balranald calcareous earths, transitional hard red and yellow duplex soils and areas of grey cracking clays are present. Many of these areas have lost their topsoil through wind and water erosion (in the case of duplex soils), or winnowing of the finer particles (in the case of the calcareous earths) (Eldridge 1985).

Dunefields of calcareous and brownish sands

Linear dunes of deep brownish sands in association with calcareous sands are found in the west and north-west of the map sheet. These support mallee vegetation. Plains and swales of brown calcareous earths and assorted duplex soils are associated with these dunes.

Plains of grey cracking clays

Self-mulching grey and yellow-grey cracking clays are associated with the rivers and floodplains. East of Balranald there is a mosaic of grey cracking clays and hard duplex soils (red-brown earths). The remains of prior streams south-east of Balranald have typically scalded margins and levees, and beds of shallow, calcareous sands. Their source-bordering dunes are composed of deep, calcareous and siliceous sands. The lunettes and rises consist of yellow duplex soils and granulated clays.

Dunes with sands and calcareous earths are highly susceptible to wind erosion if vegetative cover is removed (Semple 1989). In contrast, high clay content of the riverine plain soils reduces their susceptability to erosion.

Previous vegetation surveys

General surveys

The survey and mapping by Beadle (1948), at a scale of 1 inch: 16 miles, is the most comprehensive survey covering the whole of western New South Wales. Beadle delineated 22 major vegetation associations for the Western Division, five of which occur within the mapped area. Mallee *Eucalyptus oleosa* (referring chiefly to *E. socialis*) - *Eucalyptus dumosa* association covers much of the western half of the study area on dunefields of aeolian sandy soils. Patches of *Casuarina - Alectryon* [*Heterodendrum*] association (Belah and Rosewood) occur throughout but are more extensive to the north of the mapped area. Shrublands are important in the east, the main ones being *Maireana pyramidata - Maireana sedifolia* [*Kochia pyramidata - K. sedifolia*] association (Bluebush) and *Atriplex vesicaria* [*Atriplex vesicarium*] association (Saltbush). The river floodplains in the east and along the Murray River support forests of *Eucalyptus largiflorens* association (Black Box) [*Eucalyptus bicolor*].

Noy-Meir (1971, 1974, 1980) has produced an unpublished map of south-western New South Wales at a scale 1:1 000 000. Plants of Western New South Wales (Cunningham *et al.* 1981) and the Flora of New South Wales (Harden 1990, 1991) are the main reference books for the identification of plant species. The N.S.W. Soil Conservation Service also has a range of 'Technical Manuals' which contain a review of literature and other souces of information for various vegetation types. That Service also produced a number of 'Working Documents', which give a literature review of specific chenopod species.

Surveys specific to the Balranald – Swan Hill map area

The present distribution and status of the vegetation of the riverine forests along the Murray River, its anabranches, and the Edward and Wakool system, were assessed in a detailed survey for the Murray - Darling Basin Commission (Margules and Partners *et al.* 1990). The 1:50 000 maps produced from this survey were incorporated in this mapping project.

The maps produced from a survey of the confluence of the Lachlan with the Murrumbidgee rivers by Pressey *et al.* (1984) were also used. This study covers 88 000 ha, of which approximately 90% is on the Balranald sheet, and the remainder on the adjacent Hay sheet.

Located on the western boundary of the Balranald map sheet is Mallee Cliffs National Park. A vegetation map of the Park at 1:50 000 was produced by Morcom and Westbrooke (1990) with descriptions of the various plant communities. Approximately 90% of the 58 000 ha park is located on the Balranald sheet.

An extensive study of the mallee lands of north western Victoria (Land Conservation Council of Victoria 1987) included a vegetation map at a scale of 1:250 000. Their close proximity allows comparisons to be made between the Victorian mallee and the mallee in NSW.

The N.S.W. Soil Conservation Service has produced a series of Land Systems maps for the Western Division. The vegetation component of 22 land systems is described briefly for the Balranald 1:250 000 map sheet (Walker 1991).

Table 2. Map unit, main species and structure for plant communities shown on Balranald – Swan Hill 1:250 000 map sheet. Where communities occupy significant areas of the adjacent Ana Branch – Mildura map sheet, equivalent numbers used by Fox (1991) are given.

No.	Plant community	Main species	Structure (*Specht 1981 **Walker & Hopkins 1990)	Fox No.
1	Riverine Forest	*Eucalyptus camaldulensis*	open forest * & **	1
2	Black Box Woodland	*Eucalyptus largiflorens*	woodland *; woodland - open woodland **	2
3a	Mallee on Irregular Dunefield	*Eucalyptus dumosa, E.socialis, E. costata, E. leptophylla,Triodia scariosa*	tall shrubland *; mallee shrubland - open mallee shrubland **	
3b	Dune-Crest Mallee	*Eucalyptus dumosa, E. socialis, Triodia scariosa*	tall shrubland *; mallee shrubland - open mallee shrubland **	3
3c	Swale Mallee	*Eucalyptus dumosa, E. socialis, E. oleosa, E. gracilis*	tall shrubland *; mallee shrubland - open mallee shrubland **	
3d	Sandplain Mallee	*Eucalyptus dumosa, E. oleosa*	tall shrubland *; mallee shrubland - mallee woodland **	
4	Belah-Rosewood	*Casuarina pauper, Alectryon oleifolius* subsp. *canescens*	woodland *; open woodland - isolated clumps **	4
8	Black Bluebush	*Maireana pyramidata*	low - low-open shrubland *; open - sparse chenopod shrubland **	8
9	Pearl Bluebush	*Maireana sedifolia*	low shrubland *; open - sparse chenopod shrubland **	9
11	Bladder Saltbush	*Atriplex vesicaria, Sclerostegia tenuis*	low shrubland *; open - sparse chenopod shrubland **	11
13	Canegrass	*Eragrostis australasica*	grassland * & **	13
16	*Callitris* Mixed Woodland	*Callitris glaucophylla, Hakea tephrosperma, Hakea leucoptera*	open woodland *; open woodland - isolated trees **	
17	*Acacia melvillei* Woodland	*Acacia melvillei*	tall shrubland - low woodland *; open woodland - open shrubland **	
18	Lignum	*Muehlenbeckia florulenta*	open scrub *; shrubland - open shrubland **	
19	Old Man Saltbush	*Atriplex nummularia*	low shrubland *; open - sparse chenopod shrubland **	
20	Bull Oak	*Allocasuarina luehmannii*	open woodland *; isolated plants **	
21	Cotton-bush	*Maireana aphylla*	low shrubland *; open - sparse chenopod shrubland **	
22	Dillon bush	*Nitraria billardieri*	low open shrubland *; sparse shrubland **	
23	Great Cumbung Swamp	*Phragmites australis* *Senecio cunninghamii*	closed-open herbland *; closed-open grassland/ forbland **	
OA	Open Areas	various shrubs & grasses	low open shrubland *; sparse chenopod shrubland**	

Methods

This project is part of an ongoing vegetation mapping project of south western New South Wales. Methodology is similar to that for Fox (1991). The best available aerial photography is provided by air photomosaics 1961 to 1970 (NSW Dept of Lands) at 1:50 000. These were used to distinguish different vegetation units. Boundaries were marked directly onto the photomosaics. An initial field survey enabled names to be assigned to the vegetation units. These were then reduced and transferred to 1:100 000 topographic maps, which were used as provisional maps. The term 'community' is used for the basic vegetation unit describing areas with similar structural and floristic characteristics.

The provisional maps were field-checked. Twenty-one days of field work during 1990–1991 made it possible to check the different vegetation communities. Notes were taken on the soil type, landform, degree of disturbance of the vegetation and vegetation structure at localities over the whole of the map sheet. For some of the sites a measured area of 0.2 ha (100 m by 20 m) was thoroughly searched and all vascular plants recorded. Lignum (*Muehlenbeckia florulenta*) (community 18), and Great Cumbung Swamp (*Phragmites australis - Senecio cunninghamii*) (community 23), were not sampled due to limited access but information was available from Pressey *et al.* (1984). Areas for which surveys already exist were not sampled as extensively.

Only present-day vegetation is mapped. A combination of field notes with recent (1991) LANDSAT images at 1:250 000 were used to delineate cleared mallee and woodlands. Where possible the pre-clearing vegetation type has been indicated. Some patches of natural vegetation may be present within the areas marked as cleared and along roadsides. These may be important but could not be mapped at this scale. LANDSAT was also useful in defining structurally variable communities such as community 4: Belah-Rosewood (*Casuarina pauper - Alectryon oleifolius* subsp. *canescens*) woodland. The level of disturbance in the chenopod shrublands was variable and could not be consistently defined from the images.

Surveys for the Lowbidgee (Pressey *et al.* 1984), the Murray River (Margules and Partners *et al.* 1990), and Mallee Cliffs National Park (Morcom and Westbrooke 1990), all at 1:50 000 were referred to in compiling this map.

Many of the vegetation units also occur on the adjacent Ana Branch - Mildura map sheet to the west (Fox 1991). There are, however, slight differences in the numbering of the communities in this survey from that of Fox's survey (Table 2). In addition, the structural classification system of Walker and Hopkins (1990) has been used, as well as Specht (1981).

Within any one community, patches of other communities may occur, for example, patches of mallee in the Belah-Rosewood unit. The dominant community has been indicated on the map.

Botanical names used are those currently recognised at the National Herbarium of New South Wales.

Results

Twenty plant communities are recognised. The main structural formations are mallee shrublands, Belah-Rosewood woodland (*Casuarina pauper - Alectryon oleifolius* subsp. *canescens*), mixed woodland of *Callitris* and various chenopod shrublands. Open-forest of *Eucalyptus camaldulensis* occurs along the rivers and open-woodland of *Eucalyptus largiflorens* occurs on the periodically flooded river flats.

The communities described are mostly based on perennial species. Annuals and short-lived perennials vary with seasonal and year-to-year changes (details are given in the 'discussion' section).

A species list for the mapped area is given in Appendix 1. It has been derived from field observations and published lists.

Description of map units shown on the Balranald - Swan Hill sheet

Structure: Specht (1981) = * ; Walker and Hopkins (1990) = **

* When placed before a species name, indicates the species is exotic.

Map unit 1: Riverine Forest

Structure: open forest * & **

Characteristic species: *Eucalyptus camaldulensis* (River Red Gum)

Associated species: *Muehlenbeckia florulenta, Wahlenbergia fluminalis, Paspalidium jubiflorum, Acacia stenophylla, Eucalyptus largiflorens, Cynodon dactylon, Ranunculus lappaceus, Brachycome basaltica* var. *gracilis.*

On the extensive floodplain of the Murrumbidgee River two subunits have been described by Pressey *et al.* (1984).

Levees: *Eucalyptus camaldulensis, Carex appressa, Paspalidium jubiflorum, Wahlenbergia fluminalis,* **Cirsium vulgare,* **Sonchus oleraceus, Pratia concolor.*

Floodplain: *Eucalyptus camaldulensis, Marsilea drummondii, Phragmites australis, Eragrostis australasica, Centipeda minima, Pratia concolor, Ranunculus lappaceus, Chenopodium nitrariaceum, Atriplex nummularia.*

Soils: levees of grey, massive, non-cracking clays; at low elevations strongly gilgaied, grey self-mulching clays to massive non-cracking clays near the top of the floodplain (Pressey *et al.* 1984).

Occurrence: This community is found on the banks nearest the channels of the major rivers and creeks throughout the region, and on low-lying flats subject to flooding. The largest area of this community is found in the Lowbidgee District along the Murrumbidgee River. The densest stands of this community are along the banks nearest the river channels (Fig. 5). Extensive areas on the flats have a more 'open woodland' structure. For the length of the Murrumbidgee River within the mapped area, Black Box (*Eucalyptus largiflorens*) usually occurs as an adjacent community (2) on the floodplain flats. On parts of the Murray River the floodplain is much narrower and often the River Red Gum forest is abruptly bounded by higher ground of red/brown earths supporting mallee or *Callitris* mixed woodland, much of which has been cleared. This is most apparent along the stretch of the Murray River between the points of entry of the Wakool and Murrummbidgee Rivers.

Comments: The main tree species, *Eucalyptus camaldulensis*, is the tallest tree species in the area and forms the only 'forest' type vegetation. Inundation of varying frequency and duration is important for the survival of this species (Somerville 1988). It often occurs near Black Box (*Eucalyptus largiflorens*) which occupies slightly higher ground on the floodplain a distance from the channel, where flooding is less frequent.

Most of these forests have been logged and grazed at various times. Those most disturbed by grazing had very little ground cover and much bare earth and leaf litter at the time of the survey.

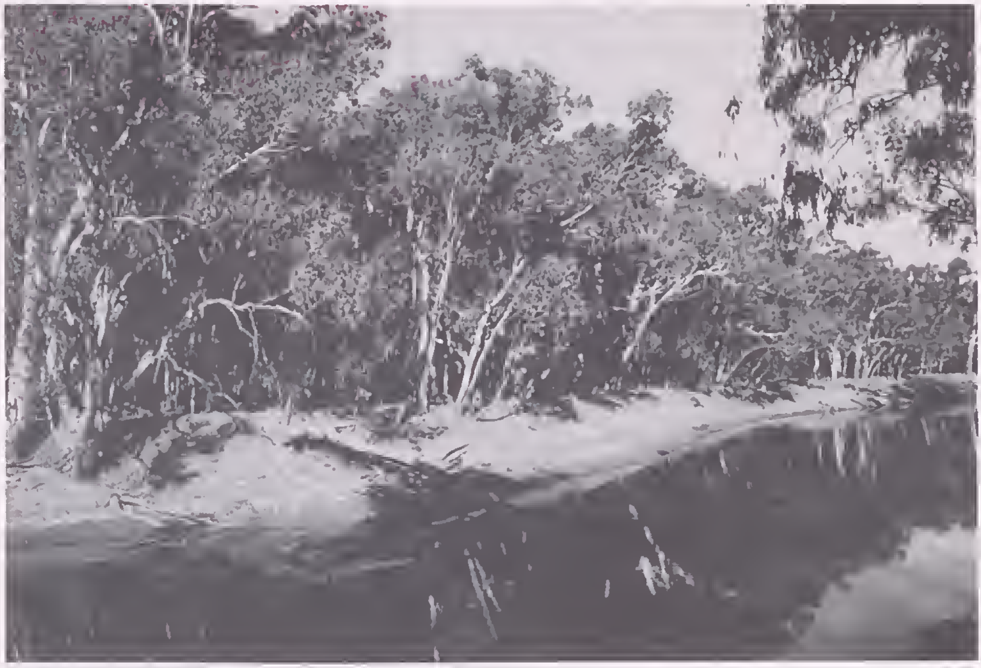

Figure 5. River Red Gum forest (*Eucalyptus camaldulensis*) along the banks of a back-water channel of the Murrumbidgee River, near Redbank Weir.

Map unit 2: Black Box
Structure: woodland *, woodland - open woodland **
Characteristic species: *Eucalyptus largiflorens*
Associated species: *Chenopodium nitrariaceum, Atriplex nummularia, Muehlenbeckia florulenta, Enchylaena tomentosa, Einadia nutans, Sclerolaena tricuspis,* often with *Chamaesyce drummondii, Atriplex lindleyi.*
Soils: Grey clays rarely cracking and with a flat or gently undulating surface.
Occurrence: Throughout the region on the uppermost level of the floodplain; beyond the floodplain it may occur in depressions along creeks, drains and old stream beds (e.g. Box Creek), and fringing ephemeral lakes (Fig. 6.). Examples of this community include Yanga Nature Reserve, the floodplain just west of Euston on the south side of the Sturt Highway, and ringing many of the lakes such as Lake Marimley, Lake Talbetts, Harveys Lake and Chillichil Lake.
Comments: Black Box woodland occurs on the floodplain of the major rivers usually beyond the River Red Gum forest. These areas are at the upper levels of the floodplain where flooding is less frequent. It also occurs along creek lines and is often seen forming a line of trees marking an intermittent or permanent creek. Areas of impeded drainage amongst other vegetation units ranging from mallee to shrublands may also support Black Box, but often as an isolated tree or group of trees. These areas, often too small to map, are most common in the region of the prior stream remains southeast of Balranald. The understorey here was often similar to the surrounding vegetation community. Yanga Nature Reserve consists almost entirely of this community. It has a more diverse understorey with the most abundant species in the Chenopodiaceae, Asteraceae and Poaceae. Within this community at Yanga are open areas of higher ground with grasses and *Maireana pyramidata* shrubland. Along the drainage

channels are Lignum (*Muehlenbeckia florulenta*) and *Chenopodium nitrariaceum*.

Chenopodium nitrariaceum is closely associated with Black Box as an understorey species, but can also extend beyond the tree line forming a shrubland. This may be seen east of Perekerten where it dominates a lake-bed, and in smaller patches south-east of Balranald.

Some areas of this unit showed only a scattered distribution of trees, for example in the Swan Hill section of the map. These areas have probably been cleared or thinned in the past.

A less common variant of this community consists of a *Eucalyptus largiflorens* overstorey with the understorey dominated by *Melaleuca lanceolata*. This subunit was restricted to a few localities within the mapped area, the main one of which is located on the Euston-Prungle road just north of Euston. Here the other understorey species are more typical of the adjacent woodland of Belah-Rosewood, (*Casuarina pauper-Alectryon oleifolius* subsp. *canescens*), with *Callitris glaucophylla* into which this community grades. They include *Olearia pimeleoides*, *Dodonaea viscosa* subsp. *angustissima*, the chenopods *Enchylaena tomentosa*, *Einadia nutans* and *Chenopodium desertorum* subsp. *microphyllum*, with many annuals including three species of *Vittadinia*: *V. gracilis*, *V. cervicularis* var. *cervicularis* and *V. dissecta* var. *hirta*. It is located on higher ground consisting of brown-red loam soil between the floodplain associated with the Murray River and the mallee country. Two smaller populations occur within the mapped area, one on the edge of the Murrumbidgee floodplain on the road to Red Bank Weir, and the other on the southern edge of Pitarpunga Lake.

A small population of *Eucalyptus intertexta* is located to the west of Euston, adjacent to the Black Box community. The area lies between the Black Box woodland, on the floodplain, and the mallee, on the raised sand country.

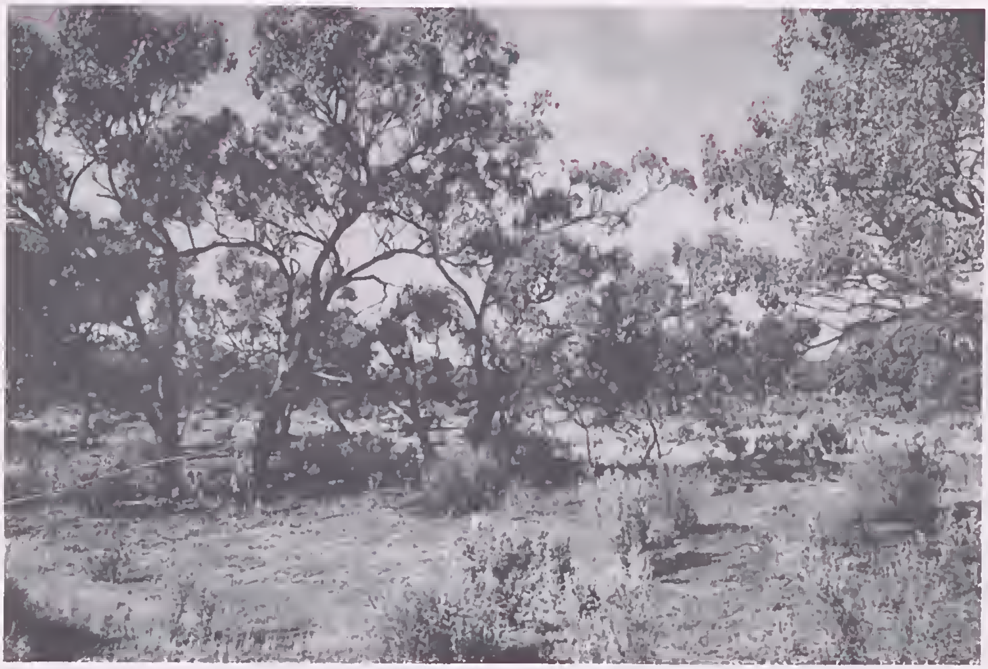

Figure 6. Floodplain with Black Box (*Eucalyptus largiflorens*) and Old Man Saltbush (*Atriplex nummularia*) in the foreground.

Map unit 3: Mallee

3a. Mallee on Irregular Dunefield

Structure: tall shrubland *; mallee shrubland - open mallee shrubland **

Characteristic species: *Eucalyptus dumosa, E. socialis, E. costata, E. leptophylla, E. oleosa, Triodia scariosa*

Associated species: *Olearia muelleri, Grevillea huegelii, Acacia colletioides, Bossiaea walkeri.*

Soils: Deep red-brown siliceous sands (Eldridge 1985).

Occurrence: The only area is in Mallee Cliffs National Park just north of Chalky Tank; it occurs more commonly to the north on the Pooncarie map.

Comments: This community consists of very even low mallee. The trees are approximately 3 m high, with many thin stems arising from the lignotubers ('whipstick' mallee, Beadle 1948). Geomorphological evidence suggests the dune landform supporting this vegetation may consist of Parilla sands, laid down when the Murravian Gulf was a marine environment between 6 and 26 million years ago (Blakers & Macmillan 1988). Even when buried, the sands influence the plant communities by altering the moisture regime of the soil.

3b. Dune-Crest Mallee

Structure: tall shrubland *; mallee shrubland - open mallee shrubland **

Characteristic species: *Eucalyptus socialis, E. dumosa, E. gracilis, Triodia scariosa.*

Associated species: *Olearia pimeleoides, Acacia colletioides, Dodonaea viscosa* subsp. *angustissima, Eremophila glabra, Eucalyptus costata, Senna artemisioides* subsp. *filifolia, Chenopodium curvispicatum, Maireana pentatropis, Westringia rigida, Myoporum platycarpum,* occasional *Callitris verrucosa.*

Soils: Deep brown calcareous and siliceous sands (Eldridge 1985).

Occurrence: Throughout the western half of the map sheet on the aeolian sands. In the north-west it is associated with Belah-Rosewood woodland (community 4) that occurs in the swales. This pattern is more common on the Ana Branch map sheet in the north-west, mapped as unit 5 by Fox (1991). Fig. 7

Comments: This community is fairly widespread in the west but varies in the frequency of dunes, which is higher on the western boundary of the map on both sides of the the Sturt Highway where the swales support community 3c. Further east the frequency decreases as the Sandplain Mallee community dominates. There are remnants of Dune-Crest Mallee found in the Kyalite area with community 3c in the swales.

3c. Swale Mallee.

Structure: tall shrubland *; mallee shrubland - open mallee shrubland **

Characteristic species: *Eucalyptus dumosa, E. socialis, E. oleosa, E. gracilis*

Associated species: *Enchylaena tomentosa, Maireana pentatropis, Maireana sclerolaenoides, Atriplex stipitata, Zygophyllum apiculatum, Zygophyllum aurantiacum, Westringia rigida, Senna artemisioides* subsp. *filifolia, Sclerolaena obliquicuspis, Acacia colletioides, Dodonaea viscosa* subsp. *angustissima.*

Soils: Brown loamy calcareous earths (Eldridge 1985).

Occurrence: Throughout the dune-fields on the western half of the map sheet associated with the Dune-Crest Mallee community of 3b, particularly south of the mosaic pattern of 3b/4. Isolated Belah (*Casuarina pauper*) occurs in some of the swales.

Comments: *Eucalyptus oleosa* tends to occur on the lowest areas of the swales, with *Eucalyptus socialis* on the dune flanks (Hill 1989). The trees are usually larger than

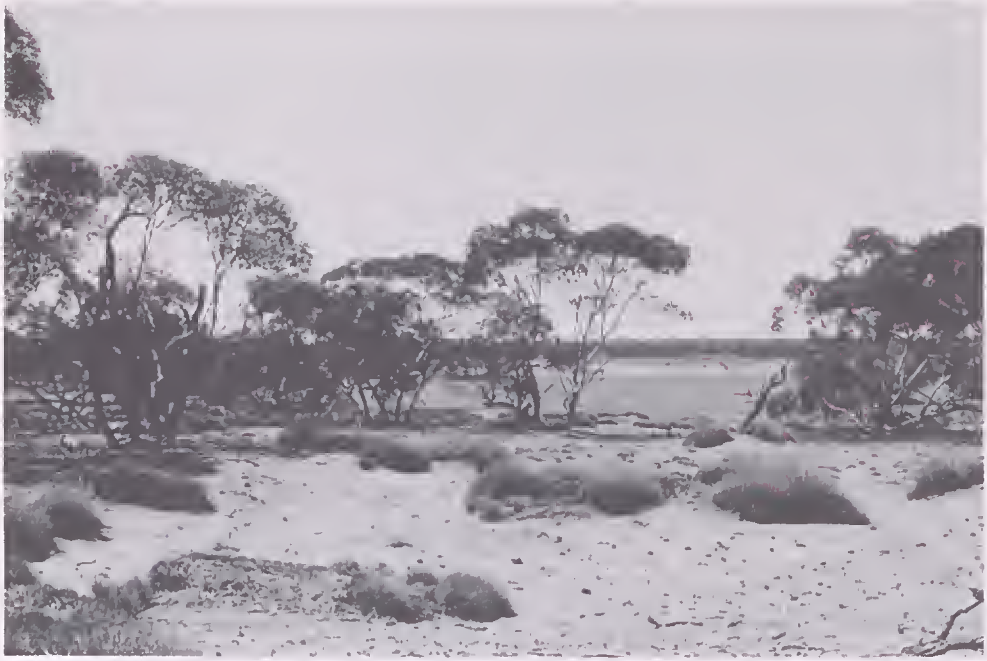

Figure 7. Disturbed sandy rise with Dune-Crest Mallee. Clumps of *Triodia scariosa* in the foreground.

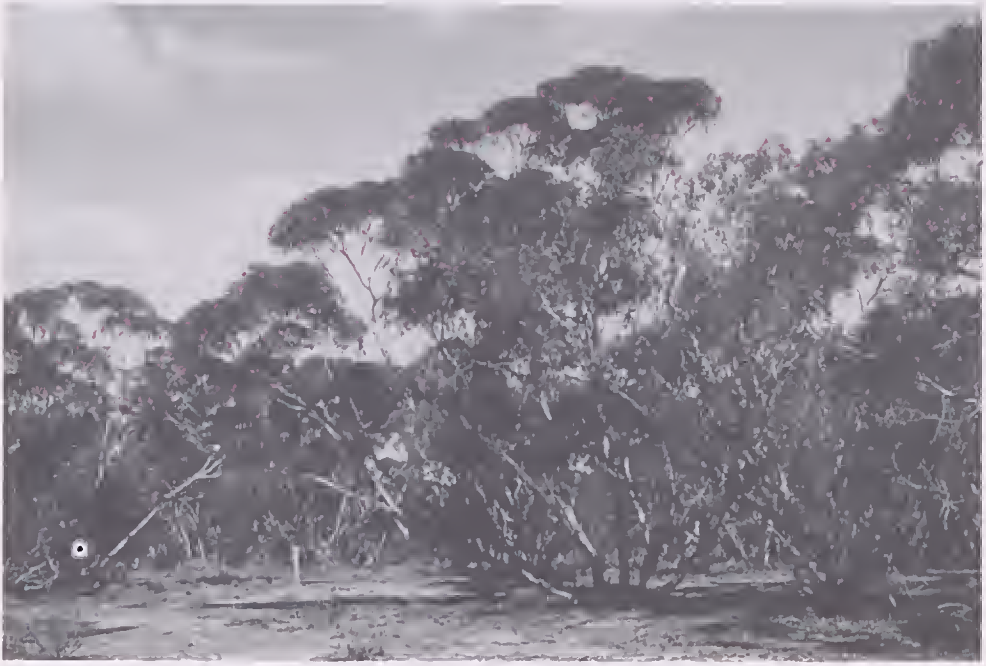

Figure 8. Sandplain Mallee along Abbots Tank - Prungle road.

those on the adjacent dune crests. This community merges with the Sandplain Mallee of 3d.

3d. Sandplain Mallee

Structure: tall shrubland *; mallee shrubland - mallee woodland **

Characteristic species: *Eucalyptus dumosa*, *E. oleosa*,

Associated species: *Atriplex stipitata*, *Zygophyllum apiculatum*, *Z. aurantiacum*, *Maireana pentatropis*, *Maireana pyramidata*, *Maireana* spp., *Enchylaena tomentosa*, *Sclerolaena obliquicuspis*, *Chenopodium curvispicatum*, **Psilocaulon tenue*, often with *Dissocarpus paradoxus* and some *Eucalyptus gracilis*.

Soils: Grey-brown loam to clay-loam calcareous earths on extensive level plains often with limestone nodules on the surface (Eldridge 1985).

Occurrence: Within transition zone between aeolian and alluvial landscapes, on southern part of the Willandra Lakes system. Flat plains with no dunes. Fig. 8.

Comments: Like the Swale Mallee the trees here tend to be larger with fewer stems. The understorey is shrubby with many chenopods. The structure becomes more open as the soils become clayier nearer the transition to the riverine plain. This form of mallee overlaps somewhat with the Swale Mallee (3c).

Map unit 4: Belah-Rosewood

Structure: woodland *; open woodland - isolated clumps **

Characteristic species: *Casuarina pauper*, *Alectryon oleifolius* subsp. *canescens*.

Associated species: *Exocarpos aphyllus*, *Olearia muelleri*, *Myoporum platycarpum*, *Enchylaena tomentosa*, *Einadia nutans*, *Sclerolaena* spp., *Maireana* spp.

Geijera parviflora in the larger stands in the north.

Soils: Brown calcareous earths on plains with isolated sandy rises; deep brown and red loam to loamy sands. *Casuarina pauper* is an indicator of the presence of calcium carbonate in the lower soil horizons (Johnson pers. comm.)

Occurrence: This woodland is widespread throughout the mapped area. In the far north of the map in the mallee sand dune country it occurs in the low-lying areas of the swales where the soil is heavier. These areas were too small to map separately but due to their consistent recurring pattern were shown as a mosaic unit (mapped as 3b/4). This unit is more extensive to the north-west of the map on the Ana Branch - Mildura sheet (Fox 1991).

Larger areas of this community have been delineated, such as a band to the north-west of 'Bidura'. Much of this has been cleared for crops. This was also the case further south in the Sandplain Mallee, unit 3d, just north of the Sturt Highway. It is also associated with old lake and river systems in the north-east of the map, often seen with *Callitris* mixed woodland in undulating country.

Dotted in the south-east on heavy clay soils associated with the floodplains between the Murrumbidgee and Edward Rivers in close proximity to unit 2, *Eucalyptus largiflorens*, Belah (*Casuarina pauper*) dominates the groves, many of which are cleared or thinned. With further sampling this may be seen as a separate unit to that in the north.

Comments: This community showed the greatest variability of all those mapped. The main canopy species is Belah (*Casuarina pauper*) with varying amounts of Rosewood (*Alectryon oleifolius* subsp. *canescens*). Both species may form single-species groves, for example, in the centre-north of the mapped area to the east of the mallee, and scattered throughout the transition zone in the middle of the map, often within chenopod shrublands. They also commonly occur as a mixture forming woodlands proper, with Belah the dominant tree species, for example in Mallee Cliffs National Park and the dune country. These characteristics are also noted by Cunningham *et al.* (1981). Beadle (1948) has a separate classification for the two dominants but at this mapping scale they have been placed in the one community. *Casuarina pauper* (Belah), is referred to as *Casuarina lepidophloia* by Beadle, and later, by authors, as *Casuarina cristata* (Belah).

Map unit 8: Black Bluebush

Structure: Low - low open shrubland *; open - sparse chenopod shrubland **

8a. Characteristic species: *Maireana pyramidata*

Associated species: *Rhagodia spinescens, Enchylaena tomentosa, Atriplex* spp., *Sclerolaena* spp., *Stipa nodosa, Stipa elegantissima,* annuals.

8b. = same community as 8a but a more sparse shrubland usually on scalded areas often associated with areas along old stream beds and lunettes, or areas that have been particularly overgrazed and/or cleared.

Soils: Red-brown sand and loam duplex soils. Deep sandy soils in which limestone exists at a greater depth than 1.2 m below the surface (Beadle 1948).

Occurrence: This community occurs throughout the whole map area, most common in the transition zone between the aeolian sand-dune country and the riverine plain. It is closely associated with lunettes and source-bordering dunes of old river systems. The best stands are in the area of the north-east corner of the map through to the boundary with the mallee country to the west. However, it also occurs south-east of Balranald. It may occur as the understorey of an adjacent woodland, such as Belah-Rosewood (*Casuarina pauper - Alectryon oleifolius* subsp. *canescens*) (community 4) near Prungle, or of mallee such as on the Prungle Mail road. Fig. 9.

Comments: This community is the most widespread of the shrublands in the mapped area. It is found on slightly higher ground than the saltbush shrublands of *Atriplex vesicaria - Sclerostegia tenuis*, an adjacent community (11) in the far north-east of the map. It occasionally grades into Pearl Bluebush (*Maireana sedifolia*) (community 9), which occupies areas of higher elevation.

The soils are susceptible to scalding whereby the topsoil is removed by wind leaving a hard bare B-horizon surface devoid of vegetation. Scalded areas have been mapped as a subunit of this community to indicate this sparse shrub cover. Grazing pressure also reduces shrub cover and heavily disturbed areas are also included in this subunit.

Map unit 9: Pearl Bluebush

Structure: low shrubland *; open - sparse chenopod shrubland **

Characteristic species: *Maireana sedifolia*

Associated species: *Enchylaena tomentosa, Rhagodia spinescens, Stipa elegantissima, Maireana pyramidata.*

Soils: Red-brown sand or loam duplex soils. Deep sandy calcareous soils in which limestone exists less than 60 cm below the surface (Beadle 1948).

Occurrence: Closely associated with Black Bluebush (*Maireana pyramidata*) (community 8) usually on slightly higher ground, such as on the crest of a rise in the undulating country in the north-east sector of the map. Occasionally occurs in open areas within the mallee country such as to the north of and along the eastern boundary of Mallee Cliffs National Park. Fig. 10.

Comments: *Maireana sedifolia* is much less common than *Maireana pyramidata* and can occur as a mixed community or as a dominant in itself. Many patches are too small to include on a map at this scale. This community is more common west of the

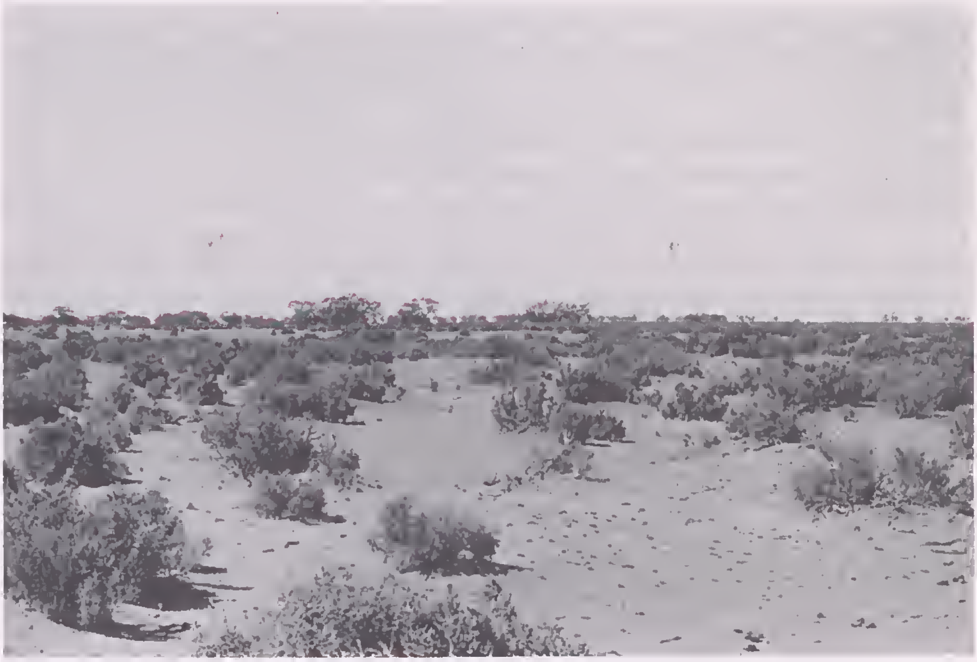

Figure 9. Black Bluebush shrubland (*Maireana pyramidata*) with very little ground cover after recent grazing.

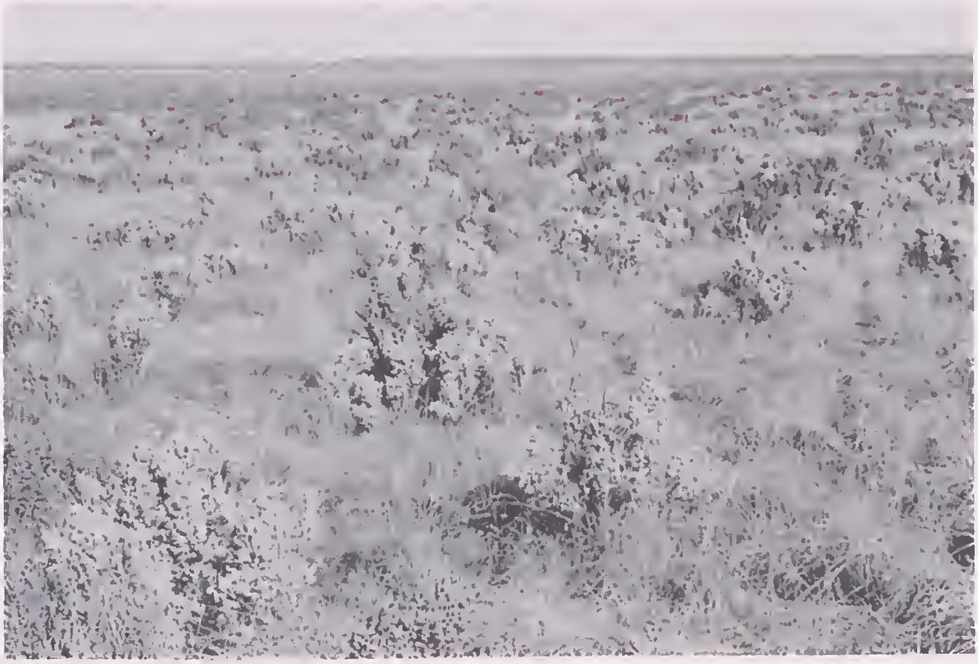

Figure 10. Pearl Bluebush (*Maireana sedifolia*) occurs on the crests of an undulating plain with Black Bluebush (*Maireana pyramidata*) downslope.

mapped area where the soil becomes more calcareous. The distribution of *Maireana sedifolia* may have been more widespread in the past, but the effects of grazing and soil changes may have seen it replaced with *Maireana pyramidata* (Beadle pers. comm.).

Map unit 11: Bladder Saltbush with *Sclerostegia tenuis*

Structure: low shrubland *; open - sparse chenopod shrubland **

Characteristic species: *Atriplex vesicaria, Sclerostegia tenuis.*

Associated species: *Malacocera tricornis, Disphyma clavellatum, Dissocarpus biflorus* var. *biflorus, Brachycome trachycarpa*, annuals such as *Plantago drummondii, Senecio glossanthus, Brachycome lineariloba, Rhodanthe corymbiflora, *Bromus rubens, *Lamarckia aurea.*

Soils: Red and brown or yellow-grey compact clay or clay-loam soils.

Occurrence: In the eastern half of the region, the vastest areas in the north. It is often broken by areas of *Maireana pyramidata* (community 8) and *Atriplex nummularia* (community 19).

Comments: There is considerable variation in the degree of dominance of the two main species, ranging from the dominance of one with the absence of the other to varying abundance of both. In the north-east corner of the map area there are extensive shrublands dominated by *Sclerostegia tenuis* with small circular depressions of Canegrass, *Eragrostis australasica. Disphyma clavellatum* also occurs in this community in certain low-lying, saline areas but is not nearly as common as it is further west (Fox 1991) and it has not been mapped as a separate unit. One example of this is along the Nap Nap road on flat areas with *Atriplex vesicaria*. This community occurs in greater extent on the Riverine Plain to the east.

Map unit 13: Canegrass

Structure: grassland * & **

Characteristic species: *Eragrostis australasica*

Associated species: *Eleocharis pallens, Juncus aridicola, Juncus flavidus, Muehlenbeckia florulenta.*

Soils: Slightly saline, compact heavy grey clay soils on which water is ponded for several months (Cunningham *et al.* 1981).

Occurrence: Generally throughout the eastern half of the area in low-lying areas of swamps, table-drains and claypans within the chenopod shrublands of communities 11 and 21. Typically occurring in small depressions (each one unmappable at this scale) within *Atriplex vesicaria - Sclerostegia tenuis* shrublands (community 11) in the north-east of the map area. Areas with the highest occurrence of Canegrass depressions have been mapped as a mosaic unit 11/13. It also occurs along the old creekline of Box Creek on the Prungle Mail road. It is seen in larger stands south-west of Perekerten and may grow with Lignum and in the riverine communities.

Comments: Areas of canegrass are subject to regular, but generally not prolonged inundation (Semple 1990).

Map unit 16: *Callitris* mixed woodland

Structure: open woodland *; open woodland - isolated trees **

Characteristic species: *Callitris glaucophylla, Hakea leucoptera , H. tephrosperma.*

Associated species: *Eremophila longifolia, Dodonaea viscosa* subsp. *angustissima, Pittosporum phillyreoides*, also at times with *Alectryon oleifolius* subsp. *canescens, Casuarina pauper* or *Allocasuarina luehmannii, Acacia melvillei, Geijera parviflora*. Near the Murray River *Callitris preissii* subsp. *murrayensis* may replace *C. glaucophylla.*

Soils: Deep coarse-textured red and brown sands and sand-loams.

Occurrence: Usually as remnants on elevated red sandy ridges occurring throughout the region, usually corresponding to old source bordering dunes of prior streams and lakes. More common in the south-east such as near Condoulpe Lake, south of Balranald, though much of this has been cleared. One of the best remnants is 2 km north-east of 'Lyle' though this would have been more extensive in the past. Raised areas of old lunette remnants on the Murrumbidgee floodplain have remnants of this community, often with *Maireana pyramidata*. These areas have been heavily grazed and much of the previous shrub cover has been removed (Pressey *et al*. 1984).

C. glaucophylla with or without associated species may occur in a mosaic with Belah-Rosewood (community 4) in the mallee dune country and the undulating country in the north to the Balranald - Ivanhoe road.

Comments: Much of this community in the south-east of the region has been cleared leaving only a few isolated individual trees or roadside patches. The understorey is often disturbed by rabbits which find this soil ideal for burrowing with its sandier texture than that of the clays of the plains further east. The only regeneration of *Callitris* was observed in roadside remnants in the Swan Hill area. The isolated trees remaining in many of the paddocks in the Swan Hill area are indicative of a greater abundance in the past. In 1836 Mitchell reported sand hills in this area 'covered with pine' (Andrews 1986). Early settlers cleared most of this community for crops and used the hard timber of the *Callitris* for fence posts and buildings.

In the south *Callitris preissii* subsp. *murrayensis* may replace *Callitris glaucophylla*. These two species readily hybridize. Only isolated trees, often in cleared paddocks or roadsides remain. This community has not been separated here for mapping purposes as its remnant nature posed a difficulty to map.

The associated species, particularly *Eremophila longifolia* and *Dodonaea viscosa* subsp. *angustissima*, are occasionally seen in the south-east of the mapped area as forming a separate shrubland on source bordering dunes. These species are known locally as woody weeds.

Map unit 17: *Acacia melvillei* woodland

Structure: tall shrubland - low woodland *; open woodland - open shrubland

Characteristic species: *Acacia melvillei*

Associated species: *Enchylaena tomentosa, Sida corrugata, Rhagodia spinescens, Nitraria billardieri*, often with **Medicago* spp., *Tetragonia tetragonioides, Goodenia fascicularis* and *Zygophyllum* spp.

Soils: Brown-red loamy calcareous earths.

Occurrence: *Acacia melvillei* may form groves as a single dominant species. The largest of these is located just to the south and the north of Balranald, where they are large enough to be mapped as a separate unit. Grazing of stock and rabbits has resulted in a sparse understorey. Some resprouting of the acacias occurs, but generally very little regeneration is to be seen at present.

Groves of smaller size occur throughout the area, less so in the mallee of the north-west. *Acacia melvillei* also appears dotted throughout the south-east of the map area, often as one or two trees, possibly remnants of once larger areas that have been cleared or grazed.

Comments: *Acacia melvillei* may have been formerly included under *Acacia homalophylla* (Yarran). These 2 species are often confused.

Map unit 18: Lignum

Structure: open scrub *; shrubland - open shrubland **

This unit was not sampled, so information has been taken from literature.

- Murray River floodplain (Margules & Partners *et al.* 1990): *Muehlenbeckia florulenta, Einadia nutans, *Bromus rubens*, with or without *Chenopodium nitrariaceum;*
- Murrumbidgee (Pressey *et al.* 1984): *Muehlenbeckia florulenta, Senecio cunninghamii, *Medicago* spp., **Phalaris paradoxa.*

Soil: Strongly gilgaied, grey self-mulching clay soils (Pressey *et al.* 1984)

Occurrence: This community generally occurs on the floodplains at a higher elevation than *Eucalyptus camaldulensis* around the fringes of grey-soil open country (Pressey *et al.* 1984). It is most abundant in the Lowbidgee Area, under River Red Gum, (*Eucalyptus camaldulensis*) and Black Box, (*Eucalyptus largiflorens*) or as vast areas of monospecific stands. On the road to 'Yanga' station much of the Lignum has been cleared for cropping.

Comments: *Muehlenbeckia florulenta* (previously *Muehlenbeckia cunninghamii*) generally occupies areas that experience relatively infrequent (e.g. once in 3 years) but often prolonged flooding (Semple 1990).

Map unit 19: Old Man Saltbush

Structure: low shrubland *; open-sparse chenopod shrubland **

Characteristic species: *Atriplex nummularia*

Associated species: *Atriplex vesicaria, Rhagodia spinescens, Atriplex* spp., *Sclerolaena* spp.

Soils: Mostly on grey and brown clay soils, usually in flat or low-lying situations. Can be found on practically all soils and at all levels (Cunningham *et al.* 1981).

Occurrence: Throughout the mapped area except the mallee, in a range of situations. Most often on grey clay soils near *Eucalyptus largiflorens* woodlands and along drainage lines. The largest areas are just north of Yanga Nature Reserve and south of Waldaira Lake. The community also occurs on red-brown earths in other chenopod shrublands such as communities 8, Black Bluebush and 11, Bladder Saltbush with *Sclerostegia*, throughout the north-east sector of the map, for example on the Ivanhoe road north of Box Creek and along the old drainage line of Box Creek following Prungle Mail road, though separate populations are too small to map. Fig. 11.

Comments: The current distribution within these communities ranges from small clumps to scattered isolated individuals. This community had a much greater distribution on the Riverine Plain in the past, but has diminished as a result of grazing (Beadle 1948). It is deep rooted and a palatable species to stock (Cunningham *et al.* 1981).

Map unit 20: Bull Oak

Structure: open woodland *; isolated plants - isolated clumps **

Characteristic species: *Allocasuarina luehmannii*

Soils: Deep brown and red sands and sand-loam.

Occurrence: This community is found on sandy rises in the south-east of the map. Usually it is seen as a few single trees, rarely in groves as in *Casuarina pauper* and usually in association with *Callitris preissii* subsp. *murrayensis.* It is more frequent further east and thought to have originally occurred in association with *Callitris* which have been removed for fencing and building purposes (Cunningham *et al.* 1981). An example in the mapped area is near 'Lyle', south-east of Balranald, in the area of mixed *Callitris* woodland mentioned in the description for community 16. Isolated trees are found on the corner of the Swan Hill and Moulamein roads south of Balranald. Also present here is Wilga (*Geijera parviflora*), *Acacia oswaldii* and *Callitris preissii* subsp. *murrayensis* and mallee nearby. This community was not extensive enough to be mapped as a separate unit.

Map unit 21: Cottonbush

Structure: low shrubland *; open-sparse chenopod shrubland **

Characteristic species: *Maireana aphylla*

Associated species: *Atriplex vesicaria*, *Atriplex leptocarpa*, *Nitraria billardieri*, *Sclerolaena* spp. and annual species *Calocephalus sonderi*, *Rhodanthe stuartiana*, **Cotula bipinnata*.

Soils: Yellow-grey and grey clay soils.

Occurrence: Restricted to the south-eastern corner of the map area on flat plain country south of the Murrumbidgee River. For example along the Keri Keri road.

Comments: This community is typical of the Riverine Plain to the east. Commonly in association with *Atriplex vesicaria*, it occupies areas of flat plain, marking the westernmost edge of the Riverine Plain. The patches are discontinuous (unlike the community on the plain further east), broken up by the other landforms and associated vegetation types of this transition zone between the plain and the mallee. Many of the associated species are indicative of disturbance from grazing, the main land-use of this area.

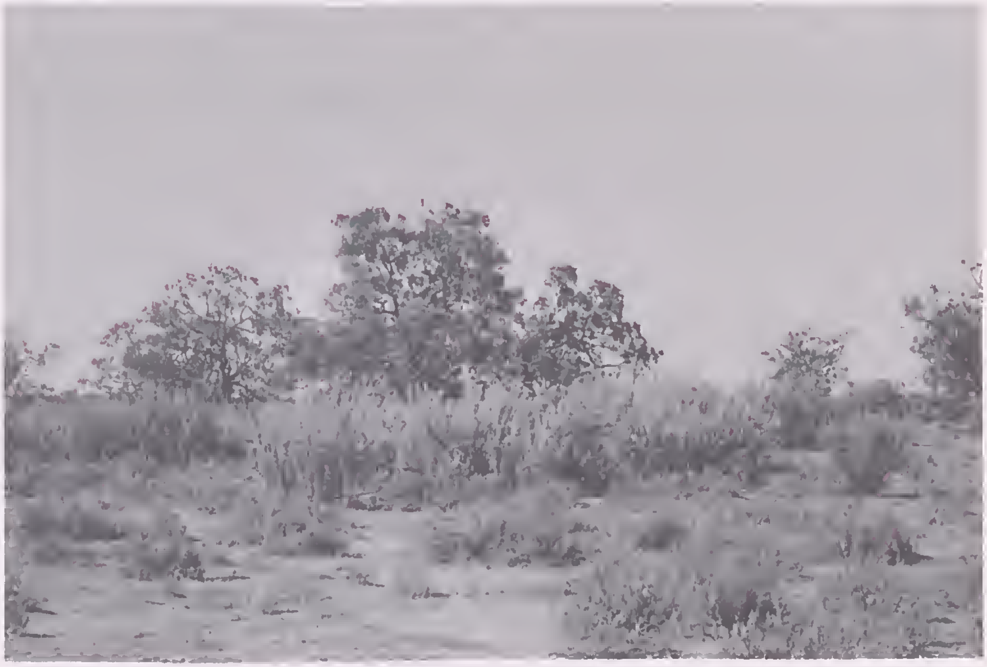

Figure 11. Old Man Saltbush (*Atriplex nummularia*) in an area of restricted drainage, with Black Box (*Eucalyptus largiflorens*) in the background.

Map unit 22: Dillon Bush

Structure: low - low open shrubland *; sparse shrubland **

Characteristic species: *Nitraria billardieri*

This community usually occupies a disturbed area and can occur within most communities as a result of overgrazing or clearing. Associated species vary depending on the original vegetation. Usually there is a high percentage of grasses, weeds and annuals with the occasional shrub for example, *Einadia nutans*, *Sclerolaena spp.* and *Atriplex spp*. Annual grasses and Asteraceae commonly occur. *Nitraria billardieri* may be present only as an occasional shrub. Before European settlement, *Nitraria billardieri* probably occurred in very small quantities in the shrubland communities (Beadle 1948). Since then, the occurrence of this species has increased with the subsequent changes in landuse (Beadle pers. comm.).

Soils: usually clay and loam soils, often saline areas. In the Lowbidgee the soils are strongly gilgaied grey self-mulching clays (Pressey *et al.* 1984).

Occurrence: On plains and floodplains throughout the region, predominantly in the east, such as dry lakebeds that have been grazed or left after cropping, overgrazed areas, and previously cropped areas.

Map unit 23: Great Cumbung Swamp

This unit was not sampled and is taken from Pressey *et al.* (1984).

Structure: closed - open herbland *; closed - open grassland/forbland **

Characteristic species: *Phragmites australis*, *Senecio cunninghamii*

Associated species: *Paspalum distichum*, **Cirsium vulgare*, *Pratia concolor*, often with **Hordeum leporinum*, and **Polypogon monspeliensis*.

Within this unit *Senecio cunninghamii* occurs on the higher ground on the edge of the swamp, with *Phragmites australis* in the swales and down to the upper limit of *Typha orientalis* which grows in the water.

Soils: Heavy clay soils.

Occurrence: In the Great Cumbung swamp at the far eastern edge of the map.

Map unit OA: Open Areas

'OA' indicates 'open areas' occurring mostly on the aeolian soils of the mallee country. They are thought to be naturally occurring areas of heavier soil (Eldridge pers. comm.) supporting shrubs, herbs and grasses. Within the Sandplain Mallee many of the 'open areas' follow old drainage lines. Within Mallee Cliffs National Park, Morcom and Westbrooke (1990) referred to these areas as 'herbland - open herbland' resulting from the modification of chenopod shrublands or arid woodlands caused by grazing pressure.

Some of the less disturbed open areas to the north of and on the eastern boundary of Mallee Cliffs National Park support Pearl Bluebush (*Maireana sedifolia*) shrubland (community 9). Close to tanks, stocking pressure may have reduced many of these areas to predominantly grasslands. South of Mallee Cliffs National Park the open areas occasionally have patches of Belah (*Casuarina pauper*). Some areas of mallee cleared for grazing in the earlier years may have partially regrown where lignotubers have not been completely removed (Fitzpatrick 1982) creating areas of open mallee. Open areas in the mallee west of Euston are a result of frequent prescribed burning. Three fires in the space of seven years have led to a depletion of mallee in the swales creating open grasslands (Noble 1984). Common species include *Sclerolaena obliquicuspis*, *Stipa nitida*, *Stipa nodosa*, often with *Dissocarpus paradoxa*, *Salsola kali*, and **Silene apetala*.

Discussion

Distribution of plant communities

The major cause of variation in vegetation in semi-arid south-eastern Australia is the interaction between soil texture and rainfall (Noy-Meir 1974, Beadle 1948). Within the mapped area the distribution of the vegetation communities also strongly reflects landform.

Aeolian landscape

Mallee dominates the aeolian sandsheet that stretches across South Australia, northern Victoria and south-western New South Wales. Within this map sheet differences in species composition and structure resulted in the four broad mallee communities described. The various mallee communities mapped overlap and grade into each other. The map attempts to reflect the major trends. A high variability of species composition was observed in the mallee which would only be objectively delineated with extensive sampling.

Dune Mallee predominates in the west and north of the map, but varies from north to south. In the north the dune-crests are dominated by Dune-Crest Mallee (3b) with species such as *Triodia scariosa*, *Eucalyptus costata* and *Callitris verrucosa* restricted to the deep sands. The swales, where the soils are heavier and have a greater clay content, support Belah-Rosewood (*Casuarina pauper* - *Alectryon oleifolius* subsp. *canescens*) (community 4). It was not feasible at this scale to map the individual clumps of Belah-Rosewood in the swales. For mapping purposes these two communities have been combined as a mosaic unit due to the consistent recurring pattern. This pattern is more extensive to the west and north of this map. This unit mapped is equivalent to unit 5 in Fox (1991).

In the south this pattern changes with swales comprising mallee (3c) with a chenopod dominated understorey. There is an occasional Belah-Rosewood (*Casuarina pauper* - *Alectryon oleifolius* subsp. *canescens*) patch but these are isolated and do not follow the pattern observed further north. Larger patches of Belah-Rosewood appear in the Sandplain Mallee in the centre of the region, though many of these have been cleared.

The sandplains are devoid of dunes and have heavier soils with a greater water-holding capacity. There is a dominance of chenopods in the understorey and the trees are often larger and with fewer stems. They are structually referred to as 'bull mallee' as opposed to 'whipstick mallee' typical of the dune crests (Beadle 1948). In western NSW these growth forms are thought to be a result of differences in soil type (Beadle 1948) or more recently, of fire occurrence (Noble 1982). *Triodia scariosa* on the dune crests is more flammable than the shrubs in the understorey of the swales and sandplains. When 'bull' mallee is burnt, often after the buildup of *Stipa* spp. in the understorey, it regenerates first as a 'whipstick' form but eventually regains its 'bull' mallee form (Noble 1982). Fire in the mallee can also create differences in floristic composition at different stages of regeneration (Brickhill 1988, Noble 1989). Within the mapped area the last major fires were in 1974-75, but there were experimental fires just west of Euston in 1980 and 1982 (Noble 1984). Open treeless areas within the mallee are flats of hard pedal red duplex soils (Walker 1991) supporting grasses and herbs. Many such areas have been caused by frequent fires (Noble 1984).

The Sandplain Mallee community correlates closely with the soil-landform association type 'O1' of Eldridge (1985). This form of mallee is similar to the 'chenopod mallee' of the Sunset country in Victoria (Land Conservation Council 1987).

A larger percentage of Sandplain Mallee has been cleared than of the other mallee types. The topography is flatter, the soil is heavier and less susceptible to erosion as well as being easier to clear.

Of higher preference for clearing is Belah-Rosewood (*Casuarina pauper - Alectryon oleifolius* subsp. *canescens*) woodland. This community occurs on the lower flatter areas within the aeolian country in the west, and on the undulating country in the transition between the aeolian landform to the riverine plain in the east. It is far more extensive to the north and north-west of the mapped area (Fox 1991, Beadle 1948). This community shows the greatest variability of all the communities mapped. Structurally it forms woodlands covering fairly large areas such as on the northern boundary of Mallee Cliffs National Park, or isolated clumps in chenopod shrublands as on the undulating country bordering the riverine plain. Floristically it commonly consists of a mixture of the two tree species, or single-species stands of either species often appearing in groves.

Often associated with the Belah-Rosewood woodlands is Black Bluebush (*Maireana pyramidata*) shrubland (community 8). This community is the most widespread of the shrublands in the mapped area. It occurs most commonly on the undulating country marking the transition from the riverine plain in the east to the aeolian sand dunes to the west. It is closely associated with lunettes and source-bordering dunes of old river systems. The soils have a lower clay content on these elevated areas than on the riverine plain. Pearl Bluebush (*Maireana sedifolia*) (community 9) is less common but also found on this landform, often mixed with and/or on slightly higher elevated land than community 8. Extensive areas of this community occur west of the mapped area and into South Australia where the soil becomes more calcareous (Scriven 1988b, Dalton 1988).

Fluvial landform

The vegetation on the eastern edge of the map sheet begins to reflect the Riverine Plain vegetation. Communities extensive on the grey-brown clays further east occur as discontinuous patches in the transition zone between the plain and the mallee. Bladder Saltbush (*Atriplex vesicaria*) with *Sclerostegia tenuis* (community 11) occurs throughout this zone but is more extensive in the north in association with Canegrass (*Eragrostis australis*) depressions. South of the Murrumbidgee River, Cotton Bush (*Maireana aphylla*) (community 21), commonly in association with *Atriplex vesicaria* occupies flat plain areas of grey clay soils. Many of the species in this community are indicative of disturbance from grazing. This trend in the shrubland communities continues further east onto the Hay Plain.

The landforms associated with the prior stream traces which cut across the Hay Plain continue into the south-east of the mapped area. The old raised stream beds and source-bordering dunes support remnant *Callitris* Mixed Woodland (community 16) and Black Bluebush (*Maireana pyramidata*) (community 8). Extensive clearing of *Callitris* has had the result that only remnants of this community remain. These remnants are highly threatened also by the grazing of stock and goats, and the destructive burrowing of rabbits, which prefer the sandier soil of this habitat to the clays of the Riverine Plain.

The only 'forest' type vegetation on the map sheet is Riverine Forest (community 1) dominated by *Eucalyptus camaldulensis* (River Red Gum). This community continues along the length of the inland rivers from NSW into South Australia, differing along its length in its associated species (Margules & Partners *et al*. 1990). Closely associated is Black Box woodland (*Eucalyptus largiflorens*) (community 2), also continuing to the east and the west, and patches of Lignum (*Muehlenbeckia florulenta*) (community 18). A comprehensive study of the Murray River system has been prepared by Margules & Partners *et al.* (1990) for the Murray Darling Basin Commission giving greater detail of the vegetation than presented here.

Old Man Saltbush (*Atriplex nummularia*) (community 19) may grow on many soil types (Cunningham *et al.* 1981) but is found in greatest numbers on the floodplains and the loamier soils of the undulating country of the 'transition zone'.

Species composition and variability of the vegetation

A total of 81 families of plants were represented in the mapped area, the main ones being Chenopodiaceae, Asteraceae and Poaceae. These families contain a large number of annual and short-lived perennial species.

A major drawback with this form of mapping in the semi-arid region is the lack of sampling throughout the year and from year to year. Similarity of plant community composition between sequential seasons in south-western New South Wales is very low, commonly 55–70%, with the turnover of the ephemeral component of the understorey very great (Fox 1990). Fox (1990) has found both the number and particular combination of species is a function of the seasonal rainfall. This mapping project has largely based the community descriptions on perennial species. Many of the annual grasses and herbs were not specific to a particular shrubland community, but are very widespread. Common annual and short-lived perennial species are the grasses **Hordeum leporinum*, **Bromus rubens*, *Danthonia caespitosa*, *Stipa* spp.; and forbs such as *Rhodanthe* spp., *Brachycome lineariloba*, **Sonchus oleraceus*, *Senecio glossanthus*, *Vittadinia* spp., (Asteraceae); *Atriplex lindleyi*, *Atriplex pseudocampanulata*, *Sclerolaena brachyptera*, *S. muricata*, *S. diacantha* (Chenopodiaceae); and a number from other families such as **Medicago* spp. (Fabaceae). A large component of the annual flora are introduced species.

Landuse and changes to native vegetation

The vegetation of the mapped area has been altered since the European settlers came to the area 160 years ago. The degree of disturbance increases generally from the north to the south of the mapped area, that is, along a gradient of water availability and better soils. The following impacts on the native vegetation were observed, but not investigated, in the course of this study.

Grazing effects

The grazing of sheep on native pastures is the main land use of the region (Semple 1989). Some cattle grazing occurs on the eastern edge of the mapped area. Grazing of the Riverine Plain in the east has occurred since 1830. By the 1840s there were reports that grazing had led to the reduction of the proportion and the regional distribution of saltbushes (*Atriplex* spp. and *Sclerolaena* spp.) replacing them with grasses (Williams 1962 & Buxton 1967 cited in Butler *et al*, 1973). Scriven (1988*b*) outlines the effects of grazing as reflected in the change in composition and biomass of the vegetation, and the compaction and erosion of the soils. Areas of Dillon Bush (*Nitraria billardieri*) (community 22) are indicative of disturbance from grazing and clearing.

The mallee country was less suitable for grazing because of its low productivity, inaccessibility and lack of reliable water supplies. However, grazing occurs throughout the mallee and in Mallee Cliffs National Park high levels of weediness can be directly linked with previous grazing history (Westbrooke 1990).

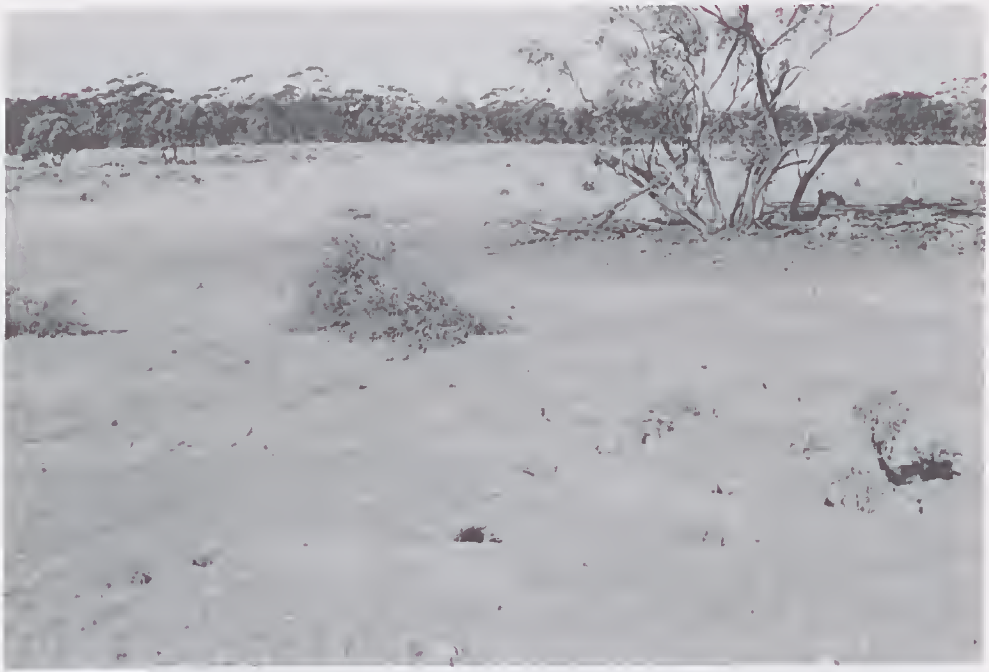

Figure 12. Disturbance by rabbits is a problem in areas with sand and loam soils, such as this area of cleared mallee.

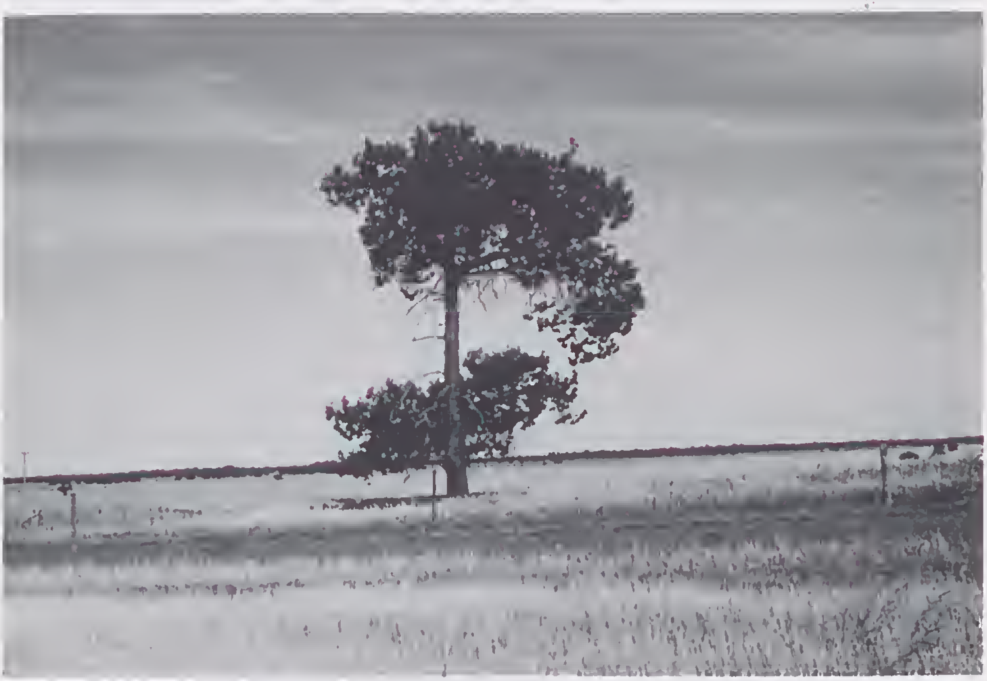

Figure 13. *Callitris* woodland has been extensively cleared for cropping and for the use of its timber. In the south, often a lone tree in a cleared paddock is indicative of its once greater abundance.

Rabbits and goats compete with sheep and native fauna for forage. This places added pressure on the native vegetation. Continual grazing changes the original herbaceous ground layer of predominantly perennial native plants to predominantly annual species with a high percentage of introduced weeds (Land Conservation Council Victoria 1987, Calder 1990). Large areas of Belah (*Casuarina pauper*) and *Callitris* woodland and 'savannah mallee' in Victoria have been so degraded from grazing that the original community is being destroyed and replaced by annual herblands and grasslands (Land Conservation Council Victoria 1987).

Lack of regeneration, particularly in the woodland communities, seen in the course of this work and by other authors (Wilson *et al*. 1976, Chesterfield and Parsons 1985) is a serious problem that needs immediate attention. Fig. 12.

Clearing and Cropping

The Weimby-Kyalite area south-west of Balranald, and the Benanee area to the north-east of Euston are major dryland cropping areas in the Western Division. They are regarded as marginal cropping areas because of the low and erratic rainfall (Eldridge & Semple 1982). The greatest clearing has occurred very recently, with a ten-fold increase in dryland cropping in the Western Division since the mid-1960s (Pressey 1990).

This agricultural use started with small-scale cropping for horse feed and was replaced by commercial cropping on soldier settlements in the 1920s (Mabbutt & Williamson 1982). Over-clearing and over-cultivation in the Benanee area caused serious soil erosion in the early years (Alchin 1980).

The original vegetation for this area was mallee and Belah-Rosewood (*Casuarina pauper - Alectryon oleifolius* subsp. *canescens*) woodland growing on calcareous sands and earths and red and yellow duplex soils. The woodland was preferentially cleared because of its more suitable soil type for cropping and the greater ease of clearing than the mallee with its large lignotubers (Stanley & Lawrie 1980). Dryland cropping has also occurred in the old lake beds around Balranald, where the previous vegetation was probably chenopod shrublands or grasslands. The principal crops are wheat, barley and other cereals.

Adverse effects of land clearing in this landscape have been outlined by authors Melville, Mabbutt, Williamson and Dodson in Mabbutt (1982), Leys (1990) and Pressey (1990*c*). They include a decline in the abundance and diversity of species, fragmentation and reduction in the area of some natural environments, and changes in the water balance of the soils that lead to soil erosion and invasion of noxious weeds.

Clearing is more extensive in the Central Division of NSW., which consists of freehold land, where there are less restrictions. Clearing in the Swan Hill area has left very little remaining natural vegetation. Only remnant trees in paddocks and on roadsides remain of the previously extensive *Callitris* woodlands (Andrews 1986). Black Box (*Eucalyptus largiflorens*) would also have covered much of the floodplain here. Fig. 13.

The Lowbidgee District to the east of Balranald and south of the Murrumbidgee River, has the most agriculturally productive land due to its fertile alluvial soil and water supply (Department of Water Resources 1991). Grazing is the dominant land-use, supplemented by the growing of agricultural crops. This area has the best stands of Lignum (*Muehlenbeckia florulenta*) in NSW (Department of Water Resources 1991). Landholders use the Lignum for grazing stock and 40% has been cleared for cropping.

In the immediate surroundings of the towns of Balranald, Euston and Swan Hill, and along the Murray River, irrigation is used for crops of predominantly grapes and citrus. The native vegetation affected in these areas would most probably have been Black Box (*Eucalyptus largiflorens*) woodlands, on the grey clay soils of the floodplain, and *Callitris* Mixed Woodland, on the sandier rises.

Fire

Fire has been used by landholders to clear mallee land, manage native pastures for maximum grazing production, and protect life and property by fuel reduction. Prescribed burning, however, is out of phase with the natural wildfires which occur in semi-arid lands every 10–15 years or longer (McArthur 1972). The last major wildfire in the area was in 1975. Prior to European settlement, however, Aboriginal burning practices would have influenced the vegetation over a long period of time. In western New South Wales generally, Aborigines used fire for food-gathering and hunting (Mullins *et al.* 1982).

The mallee communities are the most fire-prone due to the presence of a flammable canopy and grassy understorey. The buildup of speargrass (*Stipa* spp.) in the swales following good seasonal rains produces abundant fuel for fires (Noble 1984). Noble has shown, in an area west of Euston, that two or three fire events in quick succession can markedly reduce mallee densities creating open areas. Gill (1990) and Ludwig *et al.* (1990) recommend predictive modelling and monitoring of mallee vegetation and fire events to ensure species conservation.

Salinity

Salinity has been a part of the semi-arid landscape since Pleistocene time (Macumber 1990). Land use changes over the last one hundred years however, has led to a rise in salinisation. River salinity of the Murray is outlined in Margules & Partners *et al.* (1990). Dryland salinity results from a rise in the water table bringing dissolved salts to the surface. It is caused by the clearing of trees which no longer remove the water from the soil, increasing the recharge rate to the water table. Clearing and farming practices used over the last fifty years in the Balranald area have resulted in an approximate 100-fold increase in recharge to ground water (Budd *et al.* 1990*a*). The sandier soils of the mallee have higher recharge rates than the soils with a higher clay content (Budd *et al.* 1990*b*).

Salinisation has been observed at two sites near Balranald and may be contributing to poor crop yields on dry lake beds (Eldridge & Semple 1982). The land-use and prevailing climate will determine the rate of increase and future extent of salinisation (Macumber 1990). The management of soil salinity across south-east Australia is discussed in Humphreys *et al.* (1990). Retention of native vegetation, particularly mallee on the highly susceptible light-textured soils, will reduce future salinisation problems.

Feral animals

Cooke (1990) outlines the damage in mallee lands caused by rabbits, goats, foxes, cats, hares, house mice and feral pigs. The effect of grazing in the riverine communities is reviewed by Margules & Partners *et al.* (1990). Besides sheep, the two introduced animals that have greatest impact on the native vegetation are rabbits and goats. Evidence of rabbits are most apparent in the 'transition zone' between the plain and the aeolian landscape. They also prefer calcareous red earths (Parer & Libke 1985) for burrowing, leading to erosion and damage to plant roots. They destroy the vegetation by grazing and ringbarking. Poison baits and ripping of warrens is the present method of rabbit control, since myxomatosis appears to be becoming less effective. Different means of future biological control may be a long-term means of controlling rabbit numbers.

Goats are found in greatest numbers in the aeolian sand country in mallee shrublands and Belah-Rosewood (*Casuarina pauper - Alectryon oleifolius* subsp. *canescens*) and *Callitris* woodlands. Their grazing of native vegetation may lead to changes in the composition of the tree and shrub components in some woodland communities (Wilson *et al.* 1976). Whilst sheep prefer short herbs, goats are more selective in their feeding and may pull down branches and climb into bushes (Downing and Mitchell 1988).

Erosion

Wind erosion leads to the removal of nutrients, the reduction of water-holding capacity on sandy soils, and exposure of the hard clay subsoils of the duplex soils (Land Conservation Council 1987, Soil Conservation Service 1989). Where the exposed clay subsoils are saline, they are referred to as *scalds*. This is the most obvious form of erosion within the mapped area, associated with old stream traces and lake systems, for example in the system to the north-west of Morvan Tank in the north-east corner of the mapped area. Scalding was noted throughout the area in the 1940s by Beadle (1948). The process of scalding is accelerated by the removal of protective vegetation by overgrazing, clearing and inappropriate cropping practices (Margules & Partners *et al.* 1990). Methods for rehabilitation of eroded areas are outlined in Scriven (1988b). As with the salinity problem, retention of native vegetation will reduce erosion. Fig. 14.

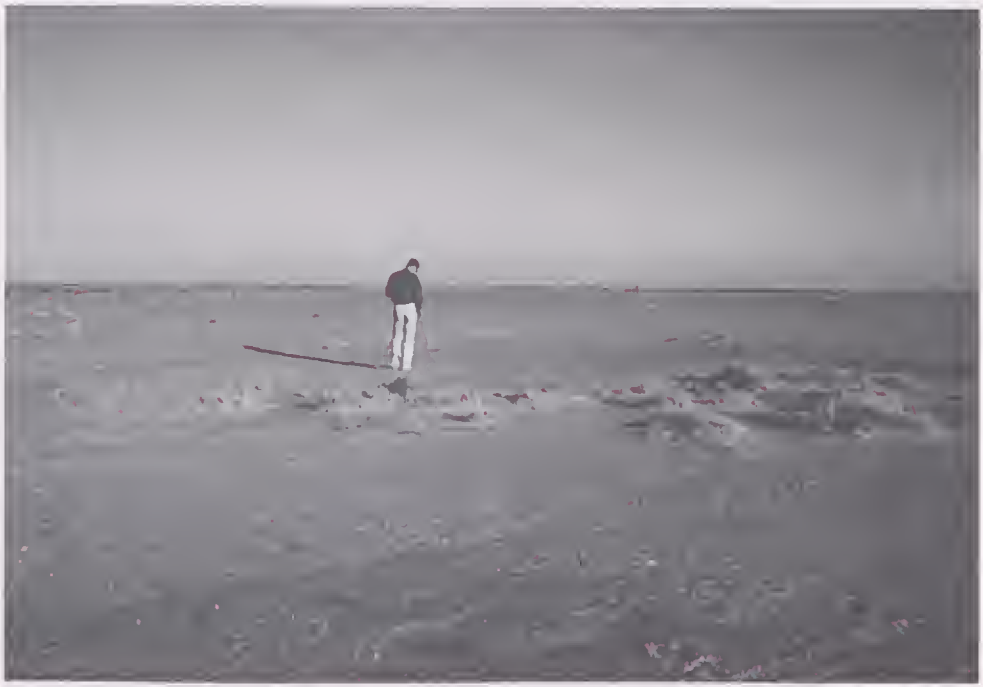

Figure 14. Overgrazing, clearing and inappropriate cropping practices may lead to vast areas of scalding.

Introduced Plants

The spread of weeds is largely associated with cropping (Eldridge and Semple 1982) and grazing (Margules & Partners *et al.* 1990, Wilson & Harrington 1984). Introduced plants seen to be particularly abundant are annuals such as **Hordeum leporinum*, **Bromus* spp., **Brassica tournefortii*, **Medicago* spp., **Sisymbrium irio*, **Sonchus oleraceus*, **Malva parviflora*. The perennial **Marrubium vulgare* (Horehound) is common along roadsides. These are replacing native perennial grasses and forbs. In all, 19% of species recorded for the mapped area are introduced. The native shrub *Nitraria billarieri* (Dillon Bush) has also colonized disturbed shrubland areas.

Conservation of the vegetation

Reserves

There are only two conservation reserves in the mapped area, and these cover only about 3% of the area.

Yanga Nature Reserve, gazetted in 1972, is located approximately 25 km by road east of Balranald. It consists of 1772 ha, mostly of Black Box (*Eucalyptus largiflorens*) woodland (community 2) with a few open areas of grasses and herbs. On a few of the raised areas are the remains of mud ovens from Aboriginal occupation of the area. These important archaeological sites are threatened by the impact of rabbits burrowing and breaking up the earthen mounds.

Mallee Cliffs National Park, gazetted in 1977, is located approximately 35 km north of Euston. Approximately 90% of the 57 969 ha is located in the mapped area, the remainder is on the adjacent Mildura map sheet to the west. The dominant plant community is mallee with areas of Belah-Rosewood (*Casuarina pauper* - *Alectryon oleifolius* subsp. *canescens*) woodland. This area contributes to the 2814 sq km or 6% of the mallee land systems conserved in the Western Division of NSW (Pressey *et al.* 1989). Rabbits and goats are a problem in the Park.

The southern-most part of the Willandra Lakes World Heritage Region occurs in the mapped area. It is a system of now dry lakes fed by Willandra Billabong Creek, a former distributary of the Lachlan River. It was declared a World Heritage area due to its outstanding cultural values (Australian Heritage Commission 1980). The lakes on the properties of 'Prungle', 'Benenong', 'Gulthul', 'Koolaman' and 'Banoon' are within the mapped area. Grazing continues in these areas under lease conditions administered by the Western Lands Commission. Mungo National Park, to the north of the mapped area, covers a part of the World Heritage area.

Conservation of vegetation communities

Benson (1989) lists the conservation status of most of the major plant communities in western New South Wales as poor or very poor, noting that the greatest impacts of European settlement have been from clearing and grazing, leading to a reduction in abundance and composition of the understorey. Within the mapped area most of the plant communities are not represented in reserves.

In the semi-arid region conservation studies have recently focussed on the mallee (Noble *et al.* 1990; Groves & Parsons 1989; Pressey *et al.* 1990*a*; Brickhill 1988; Urwin 1981). As a result some large areas of mallee such as Nombinnie Nature Reserve to the north of the mapped area, have been recently conserved.

Within the mapped area Irregular Dune Mallee (3a), Dune-Crest Mallee (3b) and Swale Mallee (3c) are represented in Mallee Cliffs National Park. Sandplain Mallee (3d) has limited representation on the eastern edge of the Park. It is the main mallee community licenced for clearing. Of this community ('chenopod mallee') 180 km^2 has been conserved in Victoria (Land Conservation Council 1987). This is 11% of the total for that state (Pressey *et al.* 1990a).

Belah-Rosewood (*Casuarina pauper - Alectryon oleifolius* subsp. *canescens*) (community 4), is also conserved in Mallee Cliffs National Park but occurs as a dominant over only 13% of the Park (Morcom & Westbrooke 1990). It is not conserved in the undulating transition zone or on the floodplain south-east of Balranald, where it occurs on the Condoulpe land system (Walker 1991). Cropping is widespread in areas occupied by this community. It also suffers from a severe reduction of understorey structure and lack of regeneration of the dominant species. Studies of the regeneration of these species have shown that grazing pressure is the major cause of decline in the populations (Chesterfield & Parsons 1985). Feral goats browse Belah and Rosewood and may change the tree and shrub component of this community (Wilson *et al.* 1976).

The *Callitris* Mixed Woodland (community 16), is one of the most threatened communities in the mapped area. It has been heavily cleared in the past and little regeneration is occurring. It is particularly vulnerable along the Murray River where *Callitris preissii* subsp. *murrayensis* occurs. Only remnants remain, often consisting of roadside trees with the understorey removed or heavily disturbed by rabbits. Most trees observed were very old and often visibly senescent. Very little recruitment is occurring.

Similarly, Bull Oak (*Allocasuarina luehmannii*) (community 20) in the south-east of the region is in poor condition. This, together with *Callitris preissii* subsp. *murrayensis*, is one of the most threatened communities in the mallee region of Victoria (Blakers & Macmillan 1988). They report that widespread degradation has resulted from grazing and weed invasion with all the best remaining areas, comprising less than 1% of the original cover, classed as 'disturbed'.

Likewise, there are no reserves conserving the riverine vegetation within the mapped area. Kemendok Nature Reserve (1 043 ha) is just west of the mapped area and is the only reserve along the Murray River in New South Wales that conserves Riverine Forest dominated by *Eucalyptus camaldulensis* (River Red Gum) (community 1). Margules and Partners *et al.* (1990) noted a general poor condition of the vegetation along the Murray River resulting from clearing, grazing, river regulation and soil salinisation.

Acacia melvillei shrubland is not conserved in any reserve system. Benson (1989) lists the inland *Acacia* and *Casuarina* shrublands/woodlands as one of the groups with the poorest conservation status in New South Wales. The scattered nature of the groves and individual plants of this species do not lend themselves easily to reserve protection. Retention of this community through altered management practices by individual property managers may be an answer to the its future survival.

Benson (1989) lists all chenopod shrublands as poorly conserved. Grazing has an impact on all the communities. None of the shrublands are conserved within the mapped area. The most threatened is Old Man Saltbush (*Atriplex nummularia*) (community 19) which has declined since European settlement. Similarly, no areas of Bladder Saltbush (*Atriplex vesicaria*) with *Sclerostegia tenuis* (community 11), Cottonbush (*Maireana aphylla*) (community 21), or Canegrass (*Eragrostis australasica*) (community 13) are reserved in the mapped area, or on the riverine plain to the east where they are more extensive.

Table 3. Species of particular conservation significance within the Balranald – Swan Hill 1:250 000 map sheet area. (a) = species nationally listed as rare or threatened (Briggs & Leigh 1988). (b) = species with restricted distributions in the Western Division of NSW (Pressey *et al.* 1990*b*).

(a)

Taxa	**Risk Code**	**Habitat**
ASTERACEAE		
Brachycome papillosa	3V	On saltbush plains on grey clay soil.
BRASSICACEAE		
Lepidium monoplocoides	3ECi	Woodlands near the Murray & Murrumbidgee River junction.
CALLITRICHACEAE		
Callitriche cyclocarpa	3V	Aquatic herb on Murray-Wakool floodplain.
SOLANACEAE		
Solanum karsensis	3RCa	On river floodplains & flooded depressions or lakebed, or disturbed area in mallee.
POACEAE		
Stipa metatoris	3V	On sandy rises with *Callitris* Mixed Woodland & mallee on red-brown sandy-loam.
Stipa wakoolica	2K	Floodplain on grey sandy-loam to clay-loam.

(b)

Taxa	**Category/ priority**	**Habitat**
ASTERACEAE		
Podotheca angustifolia	3B/4	In mallee on deep red sand.
Rhodanthe tietkensii	3B/4	In mallee on sandy soils.
Senecio murrayanus	3B/4	In woodlands.
BRASSICACEAE		
Pachymitus cardaminoides	3B/4	An ephemeral species on sandy soils.
CHENOPODIACEAE		
Sclerolaena limbata	3B/4	Heavy slightly saline soils.

FABACEAE		
Swainsona murrayana	3A/2	Grey & brown heavy clay & clay-loam soils in shrublands, Black Box & grassland communities.
Templetonia sulcata	3B/4	In mallee on sandy red earths.
MALVACEAE		
Lawrencia squamata	3B/4	In shrublands of *Maireana sedifolia*.
MYRTACEAE		
Eucalyptus porosa	3B/4	In mallee on sandy-loam soils.
POLYGONACEAE		
Muehlenbeckia diclina	3B/4	In mallee.
RUBIACEAE		
Opercularia turpis	3B/4	In mallee in the Balranald-Euston area.
SANTALACEAE		
Exocarpos sparteus	3B,4A/4	In mallee near Euston.
Santalum murrayanum	3B/4	In mallee near Euston.
THYMELAEACEAE		
Pimelea simplex subsp. *continua*	3B/4	On heavy-textured soils or sometimes in red sand.
ZYGOPHYLLACEAE		
Zygophyllum angustifolium	not yet allocated	On calcareous red & brown soils in mallee or chenopod shrublands.
CYPERACEAE		
Gahnia lanigera	3B/4	In mallee.

Risk Codes in Briggs & Leigh (1988). **2** Maximun geographic range of 100 km. **3** Range over 100 km but restricted to highly specific habitats. **E** Endangered species at risk with one or two decades under present land use. **V** Vulnerable species at risk over a longer period. **R** Rare within Australia. **K** Poorly known, field distribution information is inadequate. **Ca** adequately reserved with 1000 or more plants in a reserve. **Ci** inadequately reserved with less than 1000 plants in a reserve.

Category and **Priority Codes** in Pressey *et al.* (1990b). **3** Species restricted in the Western Division but also occurs interstate with **A**: few records, or **B**: many records. **4A** has disjunct occurrences in the Western Division with the main population interstate. **2** protection in the Western Division for these rare and/or threatened taxa is very important. **4** protection in Western Division is desirable to conserve the genetic variation within the ranges of the taxa.

Stands of Black Bluebush (*Maireana pyramidata*) and Pearl Bluebush (*Maireana sedifolia*) (communities 8 and 9) are reserved north of the mapped area in Mungo National Park. Forty per cent of the Park consists of the 'Mungo landsystem' (Walker 1991) dominated by these shrublands and Bladder Saltbush *Atriplex vesicaria*.

The Lowbidgee District has the best stands of Lignum (*Muehlenbeckia florulenta)* in New South Wales and possibly south-eastern Australia (Department of Water Resource 1991). A Plan of Management for the District by the Department of Water Resources (DWR) is near completion. Information from the draft of the management plan (DWR 1991) indicates that it is also one of the most significant wetland habitats for water birds, particularly ibis, in eastern Australia. As it is also highly productive agricultural land, clearing has removed 40% of Lignum in the last 20 years, the remainder is grazed. 'Protected lands' have been established but they do not preclude grazing activities. The water flow to the whole area is under control of the DWR. Smaller areas of Lignum occur along the Murray floodplain but have not been separated at this mapping scale (see Margules and Partners *et al.* 1990).

Conservation of species

Of all vulnerable plants in NSW, 44% occur on the western slopes and plains (Benson 1989). Pressey *et al.* (1990*b*) lists 239 plant taxa with restricted distributions in the Western Division. Of those, some species are considered endangered, vulnerable or rare (Briggs & Leigh 1988). Table 3 lists the species of conservation significance for the mapped area. Data for the rare or threatened species have been provided from ROTAP database (NSW National Parks & Wildlife Service).

Options for improving conservation

The two existing reserves conserve only a small part of the diversity of plant communities. The major conservation concerns result from the effects of the agricultural practices of grazing and clearing. The dedication of further areas as conservation reserves and the modification of land-management practices may improve the current situation.

Such improvement may be achieved by encouraging retention of native vegetation. Fencing off areas of native vegetation to exclude stock and rabbits facilitates the regeneration of the tree and shrub species and helps to restore the understorey. This is particularly necessary for the survival of the *Callitris* Mixed Woodland on the source-bordering dunes. Retention of native vegetation also is a means of preventing salinisation and soil loss.

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APPENDIX 1

Species list for communities identified on the Balranald – Swan Hill 1:250 000 map sheet. (Key on page 652).

Botanical name	Community				Other Records
	forest	mallee	w'land	shrub/grasslands	
PTERIDOPHYTES					
Adiantaceae					
Cheilanthes austrotenuifolia			4		
Azollaceae					
Azolla filiculoides	1				e
Marsileaceae					
Marsilea drummondii	1 2				
M. hirsuta					a
GYMNOSPERMS					
Cupressaceae					
Callitris glaucophylla		3b	4 16		
C. preissii subsp. *murrayensis*			16 20		
C. verrucosa		3b			
ANGIOSPERMS					
Aizoaceae					
Disphyma crassifolium subsp. *clavellatum*	1 2			11	
Glinus lotoides	1 2				
*_Psilocaulon tenue_		3c3d	4		
Tetragonia tetragonioides	2	3c3d	4	9 21	
Amaranthaceae					
Alternanthera denticulata	1 2				
A. nodiflora	2				ac
*_A. pungens_					a
A. sp. *A*				17	
Amaranthus macrocarpus	1				
Ptilotus atriplicifolius					
P. exaltatus var. *exaltatus*		3b			bc
P. nobilis		3c			
P. obovatus var. *obovatus*			17		
P. seminudus		3c			c
P. spathulatus		3b3c	4 17		
Apiaceae					
Daucus glochidiatus	2	3b	4 17	8 9 11 21	
Eryngium plantagineum					a
Asclepiadaceae					
Marsdenia australis		3c			
Asteraceae					
Actinobole uliginosum		3b	4 16 17	9	
Angianthus brachypappus				11	
A. tomentosus		3d			

Botanical name	**Community**				**Other Records**
	forest	mallee	w'land	shrub/grasslands	
Asteraceae (cont'd)					
*_Arctotheca calendula_		3c	4		
*_Aster subulatus_					ab
Brachycome basaltica var. _gracilis_	1		4	23	
B. ciliaris var. _ciliaris_		3b3d	4	8	
B. goniocarpa	2				a
B. gracilis	2				a
B. lineariloba	2	3b3c	4 17	8 9 11 19	
B. papillosa					g
B. trachycarpa	3c				
Bracteantha bracteata [_Helichrysum bracteatum_]			4 17		
Calocephalus sonderi	1 2		4 16	11 21	
Calotis cuneifolia	1 2				a
C. erinacea					a
C. hispidula		3b3c3d	4	8 9	
C. scabiosifolia var. _scabiosifolia_	2				c
C. scapigera	af	2			
*_Carthamus lanatus_	1		17		
Cassinia arcuata					b
*_Centaurea melitensis_	2	3d	4 17	8 9 22	
Centipeda cunninghamii	1 2			22 23	
C. minima	1				aef
C. thespidioides	2				ac
*_Chondrilla juncea_	1				
Chrysocephalum apiculatum [_Helichrysum apiculatum_]		3b	16		cd
*_Cirsium vulgare_	1 2			22 23	
*_Conyza bonariensis_	1				
Cotula australis	1 2				
*_C. bipinnata_				11 21	
C. coronopifolia				23	e
Cymbonotus lawsonianus	1 2				a
Dittrichia graveolens	1				af
Eclipta platyglossa	1 2				
Elachanthus pusillus		3d			c
Epaltes australis	1 2				a
E. cunninghamii					a
Eriochlamys behrii				8 11	
Gnaphalium sphaericum	2		4		ac
*_Hedypnois rhagadioloides_ subsp. _cretica_			4 17	8 9 22	
Helichrysum leucopsideum		3c			b
Hyalosperma demissum [_Helipterum demissum_]	2				c

Botanical name	Community				Other Records
	forest	mallee	w'land	shrub/grasslands	
Asteraceae (cont'd)					
H. semisterile	2		17	9 11	
[*Helipterum jessenii*]					
**Hypochaeris glabra*	1 2	3b	4 5 17	8 9 11	
**H. radicata*	2		4	9	c
Isoetopsis graminifolia	2	3b3c		9	abcd
Ixiolaena chloroleuca					a
I. leptolepis				21	
**Lactuca serriola*	1 2				a
Leucochrysum molle			4		c
[*Helipterum molle*]					
Microseris lanceolata				11	
Millotia myosotidifolia	1				a
Minuria cunninghamii			4 17	9 11 21	
M. integerrima	2				ac
M. leptophylla			17	8 9	
Myriocephalus rhizocephalus	2			11	
M. stuartii		3b	16		ac
Olearia lepidophylla		3b			
O. magniflora		3b	4		b
O. muelleri		3a3b3c	4		
O. pimeleoides	2	3b3c	4		
O. rudis					d
**Onopordum acaulon*	2				
**Picris sp.*	1				e
Podolepis canescens		3b			f
P. capillaris		3b			
P. jaceoides		3c			
P. muelleri				11	
Podotheca angustifolia		3b			
Pogonolepis muelleriana			17	9 11 19	
Pseudognaphalium luteoalbum	1				ab
Pycnosorus pleiocephalus			17	8 9 19	
[*Craspedia pleiocephala*]					
**Reichardia tingitana*			17	22	
Rhodanthe corymbiflora	2	3b	4 17	8 9 11 19 21	
[*Helipterum corymbiflorum*]					
R. diffusa					d
[*Helipterum diffusum*]					
R. floribunda	2		4	8	
[*Helipterum floribundum*]					
R. pygmaea			4 17		
[*Helipterum pygmaeum*]					
R. stuartiana		3c3d	4 16 17	8 9 21 22	
[*Helipterum stuartianum*]					
R. tietkensii					g
[*Helipterum tietkensii*]					

Botanical name	**Community**				**Other Records**
	forest	mallee	w'land	shrub/grasslands	
Asteraceae (cont'd)					
Senecio cunninghamii	1			18 23	be
S. glossanthus	2	3b3c3d	4	8 9 11	
S. lautus subsp. *dissectifolius*					b
S. murrayanus					g
S. quadridentatus	1 2	3b			
S. runcinifolius	1 2		4		
**Sonchus asper* subsp. *glaucescens*	1				ae
**S. oleraceus*	1 2	3b3c3d	4 17	8 9 11 19 22	
Triptilodiscus pygmaeus [*Helipterum australe*]	2		4		
**Urospermum picroides*					a
Vittadinia cervicularis		3b			
V. cervicularis var. *cervicularis*	2	3b3c3d	4 16		
V. condyloides			4 17		
V. cuneata var. *cuneata*	2				
V. dissecta var. *hirta*	2	3b	4		
V. gracilis	1 2				
V. pterochaeta			9		
Waitzia acuminata		3b			c
**Xanthium occidentale*	1		23		aef
**X. spinosum*	1			18 21 23	
Boraginaceae					
**Echium plantagineum*	1 2	3c	4	21	
Halgania andromedifolia		3b	4		bd
H. cyanea		3b			
**Heliotropium europaeum*	1			9	
**H. supinum*	1 2			18 23	
Omphalolappula concava	2	3b3c3d	4 17	9	
Plagiobothrys elachanthus					a
Brassicaceae					
**Alyssum linifolium*		3c	4		
Arabidella trisecta		3c			
**Brassica tournefortii*	1 2	3b3c3d	4 17		
**Carrichtera annua*		3b3c3d			
Geococcus pusillus	2		4		ac
Harmsiodoxa blennodioides					
**Lepidium africanum*					ab
L. leptopetalum		3c	4		
L. monoplocoides					g
L. papillosum					a
L. phlebopetalum					a
L. pseudohyssopifolium				21	
Pachymitus cardaminoides					adg
Rorippa laciniata	1		23		e
**Sisymbrium erysimoides*	1 2	3d	4 17	19	

Botanical name	Community				Other Records
	forest	mallee	w'land	shrub/grasslands	
Brassicaceae (cont'd)					
**S. irio*	1	3b3c3d	4		
**S. orientale*	2	3c	4		
Stenopetalum lineare		3b3d			
Callitrichaceae					
Callitriche cyclocarpa					g
Campanulaceae					
Wahlenbergia communis			17		
W. fluminalis	1 2	3b3c			
W. gracilenta			9		ac
W. luteola			4 16 17		
Caryophyllaceae					
**Herniaria cinerea*		3d		9	
**Polycarpon tetraphyllum*					a
**Scleranthus minusculus*		3b	17		
**Silene apetala*		3b3d	4 17	11 19	
**S. gallica*		3b	4		
**S. longicaulis*					a
**S. nocturna*					a
**Spergularia diandra*	2		4	8 11 19	
**S. rubra*	2		4 17	8 11 21	
Casuarinaceae					
Allocasuarina luehmannii			16 20		
Casuarina pauper			4 16	8	
Chenopodiaceae					
Atriplex acutibractea subsp. *acutibractea*		3c3d			
A. angulata		3c		8 9	
A. conduplicata			4	8 11	
A. eardleyae	2	3c	4	9	
A. holocarpa				9	bc
A. infrequens	2				
A. leptocarpa	2		4	21	
A. lindleyi	2	3c	4 17	8 9 19 11 21 22	
A. nummularia	1 2	3c3d		9 19 11	
A. pseudocampanulata	2		17	19 11 21 22	
A. semibaccata	1 2	3b3c	4	21 23	
A. spinibractea					b
A. stipitata	2	3b3c3d			
A. suberecta	2				
A. vesicaria		3b3c3d	4	8 9 19 11 21	
**Chenopodium album*					b
C. cristatum					a
C. curvispicatum [*Rhagodia gaudichaudiana*]	2	3b3c3d	4	9	
C. desertorum subsp. *microphyllum*	2	3b3c	4 16		

Botanical name	**Community**				**Other Records**
	forest	mallee	w'land	shrub/grasslands	
Chenopodiaceae (cont'd)					
**C. murale*	2				
C. nitrariaceum	1 2		4	11	
C. pumilio	1 2				
Dissocarpus biflorus					
var. *biflorus*			9 19 11		
D. paradoxus		3c3d	4	8 9 21 22	
Dysphania glomulifera	1				a
Einadia nutans	1 2	3b3c	4 16	9 19 21	
Enchylaena tomentosa	1 2	3b3c3d	4 16	8 9 19	
Halosarcia pergranulata	2				a
Maireana aphylla		2		4	9 21
M. appressa		3b	4	22	
M. brevifolia	2	3b3c3d	4	21	
M. ciliata	2		4	9	ac
M. coronata				21?	
M. decalvans	2	3a	4	21	
M. enchylaenoides		3b			c
M. erioclada		3b3c3d			
M. georgei		3c		8 9	
M. pentagona	1 2			21	
M. pentatropis		3b3c3d	4		
M. pyramidata	2	3c3c3d	4 16	8 9 19 22	
M. radiata		3b3c3d	4	9	
M. sclerolaenoides		3b3c3d	4 17	9 21 22	
M. sedifolia	2	3b3c		8 9	
M. trichoptera			4		b
M. triptera		3b3c3d	4	8	
M. turbinata		3d	4 16	8 22	
Malacocera tricornis	2			8 11 19 21	
Neobassia proceriflora					a
Osteocarpum acropterum					
var. *deminuta*	2		4	8 19	
[*Babbagia acroptera*]					
Pachycornia triandra	2				a
Rhagodia spinescens	2	3a3b3c3d	4 16	8 19 22	
R. ulicina		3b			
Salsola kali	1 2	3b3c3d	4	21	
Scleroblitum atriplicinum	2		4		
Sclerolaena bicornis		3c	4?	9 11	
S. brachyptera	2		4	8 9 11 19 21	
S. diacantha	2	3b3c3d	4 17	8 9 11 21	
S. divaricata	2		4	11 19	
S. intricata				11	
S. limbata					g
S. muricata	1 2			18 11 19 21 22 23	

Botanical name	Community				Other Records
	forest	mallee	w'land	shrub/grasslands	
Chenopodiaceae (cont'd)					
S. obliquicuspis	2	3b3c3d	4	8 9	
S. parviflora		3b			
S. patenticuspis	3c		9		cf
S. stelligera					a
S. tricuspis	2	3b	4	8 11 19	
S. ventricosa					b
Sclerostegia tenuis				11	
Convolvulaceae					
Convolvulus erubescens	1 2		4 17	8 9	
C. remotus			17		
Cressa cretica	2				a
Crassulaceae					
Crassula colorata var. *acuminata*	2	3c	4 17	9 19 21	
C. decumbens var. *decumbens*	2				a
C. sieberiana	1 2	3c	4		
Cucurbitaceae					
**Cucumis myriocarpus*	2				
Euphorbiaceae					
Adriana hookeri					c
Beyeria opaca		3c			b
Chamaesyce dallachyana	1				e
C. drummondii	1 2			9	
Euphorbia planiticola	2				c
Phyllanthus lacunarius	2				
Fabaceae-Caesalpinoideae					
Senna artemisioides notho subsp. *coriacea* [*Cassia eremophila* var. *coriacea*]		3b			
Senna artemisioides subsp. *filifolia* [*Cassia eremophila* var. *eremophila*]		3a3b3c	4		
Senna artemisioides subsp. *petiolaris* [*Cassia eremophila* var. *platypoda*]		3c	4 16		
S. artemisioides subsp. *zygophylla* [*Cassia eremophila* var. *zygophylla*]		3c	4 17		
S. artemisioides subsp. *zygophylla* x *sturtii*			16		

Botanical name	Community				Other Records
	forest	mallee	w'land	shrub/grasslands	
Fabaceae-Faboideae					
Bossiaea walkeri		3a3b3c			
Daviesia arenaria		3b			
Eutaxia microphylla		3b			bf
Lotus australis	1				a
L. cruentus	1		4		ac
**Medicago laciniata*		3c	4 17	22	
**M. minima*	1 2	3c	4 17	9	
**M. polymorpha* var. *vulgaris*	1 2	3c3d	4	19 21 22	
**M. praecox*	1		4	8 9 11 19 21	
**M. truncatula*		3c	4 17	8 11	
**Melilotus indica*	1				e
Psoralea cinerea					a
P. pallida					a
P. tenax	1 2				a
Swainsona microphylla	1				a
S. murrayana					g
S. phacoides					a
Templetonia egena		3b3c	4 17	8	
T. sulcata					g
**Trifolium arvense*			17		
**T. subterraneum*	1				e
**T. tomentosum*				22	
Fabaceae-Mimosoideae					
Acacia aneura			4		b
A. brachybotrya		3b	16		
A. buxifolia subsp. *buxifolia*		3b			
A. colletioides		3a3b3c	4		
A. hakeoides		3c			
A. halliana		3c	16		
A. ligulata	2	3b3c	16		
A. melvillei		3c	4 16 17		
A. microcarpa		3b3c			b
A. nyssophylla					a
A. oswaldii	2	3b3c3d	4 16 20	8	
A. rigens		3a3b	4		
A. salicina	1		16		
A. sclerophylla	2	3b3c			
A. stenophylla	1 2			18	
A. victoriae		3b3d		22	
A. wilhelmiana		3b			
Frankeniaceae					
Frankenia serpyllifolia	2			11	
Fumariaceae					
**Fumaria densiflora*	2				a
Gentianaceae					
Centaurium spicatum	1 2				a

Botanical name	**Community**				**Other Records**
	forest	mallee	w'land	shrub/grasslands	
Geraniaceae					
**Erodium cicutarium*	2	3c	4	9 21	
E. crinitum	1	3b3c	4 17		
Geranium retrorsum	1 2				a
Goodeniaceae					
Goodenia fascicularis			17	9	
G. glauca	1 2				aef
G. heteromera	1				a
G. pinnatifida	2		4	8	
G. pusilliflora	2	3b	4	9 19	
G. sp. (mallee *Goodenia*)		3b			
Scaevola spinescens					a
Gyrostemonaceae					
Codonocarpus cotinifolius		3b			
Haloragaceae					
Haloragis aspera	1 2				a
H. glauca	1				f
H. odontocarpa					bd
H. odontocarpa f. pterocarpa		3b			c
Myriophyllum caput-medusae	1			23	e
M. verrucosum	2			23	ef
Lamiaceae					
Ajuga australis	1 2				a
**Marrubium vulgare*	1 2	3c			
**Salvia verbenaca*		3b3c	4		
**Stachys arvensis*	1				e
Teucrium racemosum	1 2		17		
Westringia rigida		3b3c3d	4		
Lauraceae					
Cassytha melantha		3b			
Linaceae					
Linum marginale					b
Lobeliaceae					
Pratia concolor	1 2			23	
Loranthaceae					
Amyema linophyllum subsp. *orientale*	2		4		
A. miquelii	1 2	3b3c	4		
A. miraculosum subsp. *boormanii*		3b			f
A. preissii	2	3b		8	
A. quandang var. *quandang*					
Lysiana exocarpi subsp.*exocarpi*			16		
Lythraceae					
Ammannia multiflora var. *multiflora*					a

Botanical name	Community				Other Records
	forest	mallee	w'land	shrub/grasslands	
Lythraceae (cont'd)					
Lythrum hyssopifolia	1 2				a
Malvaceae					
Abutilon theophrasti	2				f
Lavatera plebeia	1		4	8	
Lawrencia squamata		3d		9	
**Malva parviflora*	1 2		4	19 21 23	
Sida ammophila	2				a
S. corrugata	2		4		
S. cunninghamii			17		
S. fibulifera	2				a
S. filiformis				21	
S. trichopoda	1 2			21	
Menyanthaceae					
Nymphoides crenata	1				e
Myoporaceae					
Eremophila bignoniiflora					a
E. deserti		3b			
E. divaricata	1 2				af
E. glabra		3b3c	4		
E. longifolia	2		4		
E. maculata		3b			b
E. oppositifolia					b
E. polyclada					a
E. sturtii			4 16	8	
Myoporum parvifolium	1 2				a
M. platycarpum		3a3b3c3d		4	
Myrtaceae					
Baeckea crassifolia		3b			bc
Eucalyptus camaldulensis	1 2			18	
E. costata		3a3b			
E. dumosa		3a3b3c3d			
E. gracilis		3a3b3c3d			
E. intertexta	2				
E. largiflorens	1 2				
E. leptophylla		3b3d			
E. oleosa		3a3b3c3d			
E. porosa		3d			
E. socialis		3a3b3c3d			
E. socialis x oleosa		3c			
Melaleuca lanceolata	2				
Nitrariaceae					
Nitraria billardierei	2	3b3c3d	4	9 18 21 22 23	
Nyctaginaceae					
Boerhavia coccinea [*B. diffusa*]	2				

Botanical name	**Community**				**Other Records**
	forest	mallee	w'land	shrub/grasslands	
Oleaceae					
Jasminum lineare			16		
Onagraceae					
Epilobium hirtigerum				23	e
Ludwigia peploides subsp. *montevidensis*	1			23	e
Oxalidaceae					
**Oxalis corniculata*	2	3b3c	4		
O. perennans	1 2		4 16 17	8 9 21	
**O. pes-caprae*					b
Papaveraceae					
**Papaver hybridum*			4		bd
Pittosporaceae					
Billardiera versicolor					b
Bursaria spinosa			16		
Pittosporum phillyreoides	2	3b3c	4 16	8 9	
Plantaginaceae					
Plantago cunninghamii	2		4 16 17	21	
P. drummondii			17	8 9 11 21	
Plumbaginaceae					
**Limonium lobatum*		3c	4		
Polygonaceae					
**Emex australis*			4		b
Muehlenbeckia florulenta	1 2			18	
M. diclina					g
Persicaria decipiens	1			23	ae
P. lapathifolia	1				a
P. orientalis	1				e
P. prostrata	1				aef
Polygonum plebeium	1				af
Rumex brownii	1				
**R. crispus*				23	e
R. crystallinus	1				a
R. tenax	2			21	
Portulacaceae					
Calandrinia calyptrata	2				a
C. eremaea	2	3b3c3d	4 17	19	
C. volubilis	2				a
Portulaca oleracea					b
Primulaceae					
**Anagallis arvensis*	1 2				a
Proteaceae					
Grevillea huegelii		3a3b3c			
Hakea leucoptera		3c	16 17		
H. tephrosperma		3c	16		
Ranunculaceae					
Clematis microphylla var. *microphylla*	2				f

Botanical name	Community				Other Records
	forest	mallee	w'land	shrub/grasslands	
Ranunculaceae (cont'd)					
**Myosurus minimus* var. *australis*	1				af
Ranunculus inundatus	1				e
R. lappaceus	1				
R. pentandrus var. *platycarpus*	1 2				a
R. pumilio	2				f
R. undosus	1				e
Rubiaceae					
Asperula conferta	1 2				
A. geminifolia	1				f
**Galium aparine*	1 2				
Opercularia turpis					dg
Synaptantha tillaeacea	1				f
Rutaceae					
Geijera parviflora			4 16 20		
Salicaceae					
**Salix babylonica*	1				a
Santalaceae					
Exocarpos aphyllus	2	3c	4	8	
E. sparteus		3b			bg
E. strictus	1 2				
Santalum acuminatum			4		
S. murrayanum		3b3c			f
Sapindaceae					
Alectryon oleifolius subsp. *canescens*		3c	4 16 20		
Dodonaea viscosa subsp. *angustissima*	2	3b3c	4 16 20		
Scrophulariaceae					
Limosella curdieana					b
Stemodia florulenta	1 2	3b		8	
**Verbascum virgatum*					b
Solanaceae					
**Datura inoxia*	1				f
Lycium australe			4		bd
**L. ferocissimum*	2		4 16 17		
**Nicotiana glauca*		3b		23	
N. velutina	2				a
Solanum coactiliferum		3b			
S. esuriale	1 2		17	9 21	
S. karsensis					g
**S. nigrum*	1 2				ae
S. simile	1				a
Sterculiaceae					
Brachychiton populneus					a

Botanical name	Community				Other Records
	forest	mallee	w'land	shrub/grasslands	
Thymelaeaceae					
Pimelea microcephala subsp. _microcephala_			16		
P. simplex subsp. _continua_		3b	16		
Urticaceae					
Parietaria debilis			4		cd
*_Urtica urens_	1				e
Verbenaceae					
*_Phyla nodiflora_	1 2				a
*_Verbena officinalis_	2				
*_V. supina_	1				
Zygophyllaceae					
Tribulus terrestris	2			21	
Zygophyllum ammophilum	2	3c3d	4	9	bc
Z. angustifolium			17		
Z. apiculatum		3b3c3d	4		
Z. aurantiacum		3b3c3d	4		
Z. confluens		3b3d	4	8 9	
Z. crenatum		3d		8 9	
Z. eremaeum		3b3c3d	4 17		
Z. glaucum		3b3c		21	
Z. iodocarpum	2	3c3d	4 17	8	
Z. ovatum		3c3d	4	8	
MONOCOTYLEDONS					
Alismataceae					
Damasonium minus	1				e
Amaryllidaceae					
Calostemma purpureum					a
Anthericaceae					
Arthropodium minus				9	c
Thysanotus baueri			17		
T. patersonii		3b			f
Asparagaceae					
*_Asparagus officinalis_	1 2				a
Asphodelaceae					
*_Asphodelus fistulosus_	1 2	3b			
Bulbine alata			17	9	
B. bulbosa					
B. semibarbata			17	8 11	
Colchicaceae					
Wurmbea dioica					d
Cyperaceae					
Carex appressa	1				e
Cyperus exaltatus	1				af
C. flaccidus					

Botanical name	**Community**				**Other Records**
	forest	mallee	w'land	shrub/grasslands	
Cyperaceae (cont'd)					
C. gymnocaulos	1 2				af
C. pygmaeus					a
C. squarrosus					a
Eleocharis acuta	1 2				
E. pallens				11 13	
E. pusilla	1				e
Gahnia lanigera		3b			f
Isolepis marginata					a
I. platycarpa	1				a
Hypoxidaceae					
Hypoxis glabella var. *glabella*					b
Juncaceae					
**Juncus aridicola*	1			13	
J. flavidus	1			23	e
J. radula				23	
Juncaginaceae					
Triglochin centrocarpa					a
T. procera	1				e
Phormiaceae					
Dianella longifolia	2	3b			
Poaceae					
Agrostis avenacea	1 2		4	11 21 23	
**Alopecurus geniculatus*	1				e
Amphibromus sp.	1				e
Amphipogon caricinus					d
Aristida behriana			17	19	
**Avena barbata*	2			9 21 15	
**Avena fatua*					
Bromus arenarius	2			19 11	
**B. diandrus*			4	22	
**B. madritensis*				9	
**B. molliformis*			4		c
**B. rubens*	2	3b3c3d	4 16 17	8 9 11 19 21 22	
Chloris truncata	2			9	
Cynodon dactylon	1 2				
Danthonia caespitosa	1 2	3b	4 16 17	8 9 11 19 21 22	
D. eriantha			17		
D. setacea	1 2				a
Digitaria ammophila					a
Enneapogon avenaceus	2				
Enteropogon acicularis	2		4 17		
Eragrostis australasica	1 2			11 19 21 13	
E. dielsii				8	
E. elongata	1				a
E. lacunaria	1 2				a
**E. pilosa*	2				c

Botanical name	**Community**				**Other Records**
	forest	mallee	w'land	shrub/grasslands	
Poaceae (cont'd)					
Eriochloa pseudoacrotricha	2				c
Eulalia aurea	1				a
Homopholis proluta				8	
**Hordeum hystrix*	2				c
**H. marinum*	1 2				a
**H. leporinum*	1 2	3b3c3d	4 17	8 9 11 19 21 23	
**Lamarckia aurea*	2			19 11	
**Lolium perenne*	1 2	3d		8 19 21	
**Panicum coloratum*	1				
Paspalidium constrictum				9	
P. jubiflorum	1 2				
P. distans	1				e
Paspalum distichum	1			23	ae
**Pentaschistis airoides*	1 2		16		a
**Phalaris minor*	1				e
**P. paradoxa*	1 2		4	11 18 21	
Phragmites australis	1			23	
Poa fordeana	1 2				
P. labillardieri	1				a
**Polypogon monspeliensis*				18 23	e
Pseudoraphis spinescens	1				a
**Puccinellia ciliata*				11	
**Rostraria cristata*	1 2			22	
**Rostraria pumila*	2		4	19	
**Schismus barbatus*	1 2	3c3d	4 16		
Sporobolus caroli				9	c
S. mitchellii	1 2				a
Stipa acrociliata		3b3c			c
S. elegantissima		3b3c	4 17	8 9 19 22	
S. eremophila			4 17	22	
S. metatoris					g
S. mollis		3b			
S. nitida	1	3c3d	4 16	8 9	
S. nodosa	2	3d	4 17	8 9 21 22	
S. platychaeta		3c			
S. scabra		3b			
S. scabra subsp. *scabra*	2				
S. trichophylla	1	3b			
S. wakoolica					g
Triodia scariosa		3b			
**Triticum aestivum*	1				a
**Vulpia myuros*	1 2	3d	16	11 21	
Potamogetonaceae					
Potamogeton tricarinatus	1				e

Botanical name	Community				Other Records
	forest	mallee	w'land	shrub/grasslands	
Typhaceae					
Typha domingensis				23	
T. orientalis	1			23	
Xanthorrhoeaceae					
Lomandra glauca		3b			f
L. leucocephala subsp. *robusta*		3b3c	4		bd
L. leucocephala subsp. *leucocephala*		3b			

Key

[ ] names in square brackets are synonyms.

a = Margules and Partners Pty Ltd, P. & J. Smith Ecological Consultants, & Department of Conservation Forests and Lands Victoria (1990) *River Murray riparian vegetation study* (Murray-Darling Basin Commission).

b = Morcomb L. & Westbrooke M., (1990). The vegetation of Mallee Cliffs National Park. *Cunninghamia* 2(2):147-165.

c = M. Fox study sites. Unpublished data (Royal Botanic Gardens, Sydney).

d = W.S. Semple (1979) *Species list for "Mallee Cliffs"* Soil Conservation Service of NSW

e = Pressey, R.L., Bell, F.C., Barker, J., Rundle, A.S. & Belcher, C.A. (1984) *Bio-physical features of the Lachlan-Murrumbidgee confluence, south-western New South Wales.* (N.S.W. National Parks and Wildlife Service).

f = A. Parsons (Unpublished species list for the area south of Mallee Cliffs National Park to the Murray River (NSW National Parks & Wildlife Service, Sydney).

g = Species of particular conservation significance within the mapped area (see Table 3).

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A national register for the fire responses of plant species

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Abstract

Gill, A. Malcolm[1] & Bradstock, R.A.[2] ([1] CSIRO Division of Plant Industry, GPO Box 1600, Canberra, ACT, Australia 2601; [2] NSW National Parks and Wildlife Service, PO Box 1967, Hurstville, NSW, Australia 2220) 1992. *A national register for the fire responses of plant species.* Cunninghamia *2(4): 653–660*. Currently, approximately 1 500 vascular plant species have been classified in relation to their fire responses and included in a national fire response register. In a cooperative scheme to which new contributors are welcome, data are being assembled in order to assist in the development of practical scientifically-based monitoring systems for fire-prone plant species. Other uses of the data are to discover species which show ecotypic variation; or, show varying responses depending on the nature of the fires or environments to which they are exposed. The data collated also may be used to help explain ecosystem dynamics through models (e.g. Noble & Slatyer 1980). Fire-response categories are based on the schemes of Noble & Slatyer (1980) and Gill (1981 *a* & *b*). Further data being collated are for life form, conservation status and longevity.

Introduction

Knowledge of the responses of plant species to fires is of intrinsic interest but the information can be used also in the development of practical, soundly-based monitoring systems for fire effects in state forests, national parks and nature reserves. In a pilot system developed for Nadgee Nature Reserve, Gill & Nicholls (1989) used response data for species collected by observers not just at Nadgee but also at other sites, sometimes in other States. This paper reports the initiation and development of a fire response register to facilitate the accumulation and transfer of knowledge across Australia as a means towards the establishment of scientifically based, but practical, monitoring systems for vascular plant species in state forests, parks and reserves. An urgent priority for the fire management of native landscapes today is for effective monitoring systems; with their development and implementation, resource managers will be able to demonstrate their success in the management of plant-species biodiversity.

The aims of this paper are:

(i) to describe the nature of the data being collected and collated;

(ii) to provide the rationale for the adoption of categories of data chosen;

(iii) to examine some of the difficulties involved in classifying certain species and, thereby, encourage study of their autecology;

(iv) to advise scientists and naturalists of the establishment of the register and invite contributions to it.

The register

The register categorises the responses of species to fires but does not provide the basis for the prediction of *population* behaviour in relation to fire regimes (combinations of frequencies, intensities and times of occurrences of fires) in a detailed quantitative way. Nonetheless, the sort of classification described here may flag extreme responses of species to particular fire regimes, such as extinction due to the occurrence of a fire before the onset of flowering in a fire-sensitive species.

Nomenclature for the register follows that of the recent National Checklist of Australian vascular plant species compiled by Hnatiuk (1990). Before entry into the register, species names are standardised according to the national checklist.

Data recorded in the register are:

(i) species (from checklist) - family, genus, species;

(ii) life form - tree, shrub, non-geophytic herb or graminoid, geophyte, epiphyte (including mistletoes);

(iii) fire-response - fire-response category and observer's name;

(iv) longevity - annual, biennial, perennial;

(v) origin - native, exotic;

(vi) other available data, e.g. response at a particular life-cycle stage (seedling, immature, adult, senescent - an additional line entry), primary juvenile period in years after fire for particular areas (local data only as subject to local variation) and special-case fire-regime vulnerability. Whether the species is rare or threatened (Briggs and Leigh 1988) would be identified from current lists.

Which classification of species responses?

There are many species classifications for species in fire-prone environments. They may be divided into three groups: (i) mechanistic; (ii) consequential; (iii) strategic.

'Mechanistic' classifications attempt to group species which have similar means of resistance and recovery in the face of fire. An example of this is the classification of Gill (1975) which distinguishes, among other things, plants that owe their immediate resistance to the thermal properties of a layer of bark or to those of a stem with dispersed vasculature.

'Consequential' classifications are unconcerned with mechanism; the end result is all that matters. An example of this is the scheme devised by Noble and Slatyer (1980) which concerns itself with, among other things, whether or not plants survive a fire rather than how that occurs.

'Strategic' classifications are those which imply behavioural action and tend to be evolutionary in perspective: examples are the classifications of Rowe (1983) and Frost (1984). These distinguish species which are 'evaders', 'resisters', 'endurers', etc. (see also Naveh 1975).

The three approaches outlined above are, in fact, not completely distinct; there are many intermediates and, indeed, the different systems often use similar criteria in arriving at their classifications. Perhaps the mechanistic approach is the most distinct at present. The most comprehensive classification is that of Noble and Slatyer (1980) which includes not just the way a species survives a disturbance, but also its ability to become established and the timing of important events during its life history. No one scheme completely satisfies all users (and uses), nor, perhaps, all circumstances and all levels of knowledge of species' properties.

'Adaptive traits', 'vital attributes' and 'species characteristics'

The most enduring criterion for species response to fires is whether persistence through the event is by seed ('seeders'), or by vegetative means ('sprouters') (e.g. Jarrett & Petrie 1929). Given exposure to the same level of leaf damage (explicit in the classification of Gill (1981*a*) as 100% leaf scorch, but rare elsewhere), most species seem to fall quite readily into one or other of these categories. Even without explicit attention to the level of damage, many species may be readily classified. Beadle (1940), for example, listed the percentage survivals of plants belonging to 13 shrub species without specifying any level of damage: 11 species recorded either 100% death or nil death while the other two were within 12% of these extremes. However, there are species which do have intermediate responses which cannot be attributed to extrinsic factors: Hodgkinson and Griffin (1982) noted that, among the 13 shrub species they observed, mortalities of populations of 10 species were mostly within the range 0–30% or 70–100% while the remaining three species had intermediate mortalities. As a general rule, if mortality within the population with 100% leaf scorch is greater than 70%, then the species would be a 'seeder' species; if mortality is less than 30%, it would be a 'resprouter' species. If there is any doubt into which category a species should be placed, because of intermediate behaviour, the species is better put into both categories with annotation (with a two-line entry into the register).

One expected outcome of the register is to find species which have different responses in different places. In some cases such finds may lead to the discovery of new species such as the *Hakea* species studied by Lee (1984). In other cases, such as hummock grass *Triodia irritans* found in semi-arid NSW and Victoria, resprouting has been observed near Mt Hope, NSW, and in Wyperfeld National Park in northwestern Victoria, but complete mortality has been observed to be a consequence of fire elsewhere (Bradstock 1989). A forest example is *Acacia dealbata* which in mesic forest areas is a 'seeder' but elsewhere is a 'resprouter'(Ashton 1981).

Naveh (1975), in Israel, distinguished three categories of species, viz. 'facultative root resprouters'(termed 'resprouters' here), 'obligatory seed regenerators' (termed 'seeders' here) and 'obligatory root resprouters'. The last of these categories was for species which did not reproduce from seed after fire but did do so vegetatively (i.e. a subsection of 'resprouters'). We do not know whether or not 'obligatory root resprouters' fail to regenerate from seed because there is none available at the appropriate time or because seed present is not stimulated to germinate. The simplest hypothesis is that there is no seed available. If so, knowing that a species falls into this category has particular value in predicting species response to a rare extreme drought (or bulldozing, for example) which may kill the vegetative population. However, classifying a species into this category is difficult because it implies that the reproductive behaviour of the species through time is well known: species with episodic regeneration may seem to be bereft of a seed supply most of the time but may depend on a rare reproductive event for the long-term replenishment of the population.

Noble & Slatyer (1980) and Gill (1981*a*) subdivided the seed regenerators into three identical groups, viz. those that depend on external sources of seed for their representation in the burned area, those that depend on seed stored in the soil for regeneration, and those that depend on canopy-stored seed. The diaspores of species in these three groups show particular morphologies and means of responses to fires, such as hard seededness (many leguminous species - Auld & O'Connell 1991), succulent fruits assisting dispersal (e.g. mistletoes), and containment in large woody fruits (e.g. *Hakea* species). It is tempting to subdivide those species that disperse seed back into an area after fire according to the nature of the diaspore (winged seed, succulent fruit, spore) but the numbers of species involved are small and, therefore, subdivision may be unwarranted. Noble & Slatyer (1980) also had another group which may be seen as a subgroup of those that depend on seed for regeneration; this 'subgroup' was for species that had no available seed storage while the plant was in the juvenile stage (only), a useful subgroup for species such as the annual *Sorghum* species of the Northern Territory which can be eliminated locally by deliberate application of fire in the wet season (Stocker & Sturtz 1966).

We draw attention to a class of species with canopy-stored seed which seems to have been little discussed morphologically. Previously, the canopy-store category has been thought of as containing only species with woody fruits which protected the seed from fire during its passage. However, there are certain *Acacia* species which, when their pods split and reflex, expose seeds which remain on the canopies for considerable periods (O'Dowd & Gill 1986). This seed is likely to be vulnerable to fire. Some of these *Acacia* species, at least, would be expected to have seed stored in the soil as well, and would be best characterised on this basis rather than on canopy storage if the host plants are fire sensitive. An extreme case of this seems to be *Acacia cyclops*, a shrub of coastal areas of Western Australia and South Australia. *A. cyclops* shows storage of seed on canopies for long periods (O'Dowd & Gill 1986) but few seeds stored in the soil, apparently because seeds in soil are destroyed by hemipteran predators (Gill & Neser 1984). In Australia, it would be classified best, on the basis of present knowledge, as a 'seeder' reliant on external seed sources for its re-establishment. In South Africa where it is introduced, however, it would be characterised best as a 'seeder' species with soil-stored seed; there, it stores considerable quantities of seed in soil (see Gill & Neser 1984). These classifications for *A. cyclops* assume that any seed present on the bush at the times of fires would be destroyed or killed. Canopy seed storage also occurs in *Gahnia melanocarpa*, a robust, stemmed sedge, which displays persistent small seeds on thin threads dangling from the parent inflorescence; in this case, however, *Gahnia* is a species which usually survives fire and regrows from terminal buds - a 'resprouter'.

Among the vegetatively regenerating species, Gill (1981*a*) distinguished four categories viz. those regenerating from basal buds, root suckers, epicormic shoots (from aerial stems), or from large aerial apical buds unaffected by the fire. Regeneration from basal buds was distinguished from regeneration by root suckers because the latter have the potential for population growth after a fire event but the former do not. Mature plants regenerating from aerial sources comprised the last two categories of vegetatively regenerating plants: these were distinguished because the mechanisms of response are so different. Species which regenerate from epicormic shoots are trees or tall shrubs which may replenish their leaf populations quickly after fire and thereby shade their competitors. Species which regenerate from large apical buds, like many Xanthorrhoeaceae, may also have a fire-induced flowering response (Gill 1981*b*).

The fire-response categories distinguished for the purposes of the register may be determined from the key in Table 1. Note that while all categories in the table apply to woody plants, not all apply to herbaceous plants. In particular, there will be no entries for herbaceous plants in categories 1 and 6.

Table 1. Key for the classification of species according to their fire responses (after Gill 1981*a*).

Mature plants just subject to 100% leaf scorch from fire die (category 8 if no further data available):

* Propagules present after fire's passage are in the form of viable canopy-stored seed .... **Category 1**
* Propagules present after fire's passage are in the form of soil-stored seed .... **Category 2**
* No propagules remain on the site after fire .... **Category 3**

Mature plants just subject to 100% canopy scorch survive (category 9 if no further data available):

* Resprout from root suckers or rhizomes .... **Category 4**
* Resprout from basal stem buds such as those in lignotubers .... **Category 5**
* Resprout from epicormic shoots .... **Category 6**
* Regrowth from unharmed, usually terminal, aerial buds .... **Category 7**

Additional data

The idea of the 'additional data' is that more detailed information than the species response only can be incorporated into the system. For example, if it is observed that a species at a particular life stage has a response that is different from that expected from the mature-plant response, then an extra entry can be made by repeating the species' name in the register (with life stage bracketed after it) and noting the response at that stage. A similar multiple entry can be made if there is a geographic variation in response (with geographic location bracketed) or a seasonal variation (with season bracketed).

The tolerance categories of Noble & Slatyer (1980) were considered for inclusion in the register but it was concluded that the level of detail they provide is beyond the broad scope of the purposes here defined. In the future, categories such as these may be worth including as the system moves towards a population level classification.

Further species data are needed if events such as the demise of populations of the annual tropical grass *Sorghum intrans* with a single wet-season fire (Stocker & Sturtz 1966) and the rapid depletion of mallee eucalypts with a series of annual or biennial autumn fires (Noble 1989) are to be predicted. While these events are unknown outside of deliberate human intervention, their occurrences have far reaching consequences.

In the case of annual *Sorghum* (Stocker & Sturtz 1966), the important point is that all propagules present were simultaneously vulnerable to fire at a particular stage of the life cycle. For the mallees, normally resprouters, vulnerability to a particular sequence of events occurred when all plants were at the same stage of regeneration and there was no seed present. Similarly, the 'obligate resprouters' may be seen as having populations which are synchronously vulnerable to particular events. Such circumstances as those described here in this section are considered to be, in general, beyond the resolution of the classification.

Life forms: vascular epiphytes

In our simple classification of life forms, we have included the category of 'vascular epiphytes' (taken broadly to include mistletoes) because of the special survival circumstances to which such plants may occur in relation to fires: they may be at various heights in the canopy of the host and, therefore, have positional protection (although they would have the same species response category as determined from Table 1); and, they may occur on host tissues with varying survival potential during fires. We know of no quantitative information on the fire responses of vascular epiphytes and their hosts.

Local use of the classification

Local use of the data in the register may involve the determination of juvenile periods, plant longevity and the minimum time interval between fires if predictions are to be made of local survivorship of the species given fires of an intensity sufficient to scorch plant canopies. For example, if the species has its entire population in the vegetative state and it is fire sensitive, then the population will become extinct when fire sufficient to scorch all the plant canopies occurs; if the population dies out before fire occurs, then it will become locally extinct also (assuming no seed in the soil in this case); if seed production occurs but is inadequate to completely replace the parent population when fire occurs, then repeated fires at the same interval will eventually cause the population to become extinct. Because of the importance of the fire interval of the most sensitive species, it is important to know the primary juvenile period (Gill 1975) of various species. This period varies from place to place (Benson 1985) but it is possible that the same two species at two different sites may have different juvenile periods but show the same relative chronology in coming to flower at each site.

The interval between fires varies widely from place to place and at the one site. A recent extreme occurred for heathland near Sydney when a small portion of an experimental site, burned a few weeks previously, was again burned when a severe unplanned fire occurred. Examples of two fires within a year are coming to light in the Sydney heathlands, such as in parts of the Royal National Park. Such examples are important because local declines, even extinctions, of vegetatively resprouting species could occur if short intervals between fires are repeated often enough (Bradstock & Myerscough 1988, Bradstock 1990). We know very little about relative sensitivities among resprouters to such events though there are parts of northern Australia that are routinely subject to annual fires.

Conclusions

This scheme is a national scheme but State nodes are envisaged which would collate and distribute State information. Already, people in Victoria, NSW, SA, Qld, WA and the ACT have indicated their willingness to take part in the scheme.

The national register, to date, has been compiled from unpublished sources as well as the literature. There are currently about 1 500 entries; most of the data are for mallee, heath and forest lands.

The State species check lists may be drawn from the master national checklists such that all contributors are working according to the same nomenclature. The system can operate on personal computers.

In the future, species response data to types of 'disturbance' other than fires are envisaged. Such data, fed into monitoring or other managerial systems, should provide managers with tools to assist them further in their management of our native landscapes. Eventually, demographic classes may be used to replace species' classification in designing monitoring systems.

Acknowledgements

For comments on the manuscript, we would like to thank R. Groves, J. Hoare, K. Hodgkinson, D. Keith and G. Wardell-Johnson. The register has been initiated with the financial assistance of the Murray Darling Basin Commission.

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REVIEW

Vegetation description and map, Ipswich, south-eastern Queensland, Australia, scale 1:250 000.

J. A. Elsol, Queensland Botany Bulletin No. 10. Brisbane: Queensland Department of Primary Industries, 1991. 61 pp. + col. map, 92 x 58 cm. Price $22.00

Traditional vegetation survey and mapping, at times regarded as an old-fashioned methodology, is becoming increasingly attractive as land management agencies discover that such surveys provide an essential data source for their computerised database and geographical information systems. As a result, vegetation ecologists are being encouraged to carry out more vegetation mapping and site survey, providing data for the managers (hopefully!) to answer all sorts of difficult questions (both scientifically and politically), on land use and conservation issues.

This situation, however, also provides ecologists with an opportunity, indeed responsibility, to provide careful interpretation and assessment of such data particularly in terms of environmental impact and change, and long-term sustainable land use and conservation. Such assessments carry added weight in being made by the scientist possessing more contextual information than can readily be documented or databased (e.g. first-hand field inspection of many sites).

The Ipswich vegetation map shows 17 map units grouped and coloured according to structure. Each map unit consists of between one and eleven vegetation types. There are 33 woodland and open-forest vegetation types and a further seven closed-forest types. Each is described in detail in the accompanying text emphasising tree species – percentage frequency, basal area, species/site – but also with lists of small trees, shrubs and grasses, locations, altitude, geology, aspect and comments.

However, the scientist's interpretation and assessment are missing. There is no discussion of the nature of the vegetation of the map sheet in terms of community dynamics, viability or sustainability, or even conservation issues. This is an essential ingredient for making meaningful decisions if the data, clinically provided, classified and pigeon-holed, is to be plugged into a GIS, ready to provide *objective* answers.

This shortcoming appears to be related to the intent of the study i.e. *to overlook the last two centuries of human settlement by mapping the vegetation of the area as though it was in an 'undisturbed pre-European-settlement condition'* (p. 1). Whilst it is certainly appropriate to study and map an area in terms of its pre-European condition, much of the value in doing so is as a basis for interpreting current and recent-past vegetation and land use patterns. Much of the understanding that the researcher gains in doing the work is lost if it is left out of a publication like this. For example, there are data from over 250 sites. Assuming that the author visited the majority of these he would have developed a broad understanding of current land use conditions and potential conservation issues and their significance. The scientific view of these issues needs to be provided. If the ecologist, with extensive field knowledge and understanding, does not provide interpretation that leads to guidelines on issues of scientific importance, how can we expect managers to make the most appropriate decisions.

As far as the map itself is concerned, there is no indication that it shows 'pre-settlement' vegetation rather than 'present-day' vegetation (except by reference to the text summary) and the user could be forgiven for thinking that the Ipswich area was still completely covered with closed-forest, open-forests and woodlands, which it is not. It would have been most helpful to have present-day vegetation coverage shown as a hatching or in a small inset map. There is also space on the map sheet for a much more detailed legend to reduce frequent reference to the text.

Delving deeper into the map unit descriptions, it is unclear how these have been defined. The methods used in developing the classification and how the vegetation types, map units, tree species associations and site groups are related, are not clearly explained. Some of the botanical nomenclature is not current, e.g. *Eucalyptus propinqua* var. *major* has been generally regarded as *E. major* since Blakely (1934),(including *Flora of Australia* 1988), but I understand the difficulties that ecologists face in keeping up with ever-changing nomenclature.

Published printed maps, not just possible access to digitised data, are essential if appropriate knowledge on vegetation patterns and composition is to reach users such as land managers, local government authorities, conservationists, environmental consultants, educators and other interested persons. I urge potential users to purchase copies of this map. Though the information gathered has not been fully expressed, it provides very detailed data on the vegetation of the area. However, as an effective publication, the map and text need far better interpretation, and I urge users to inform the Queensland Department of Primary Industries that they want future maps in the series to be more informative and user-friendly. There would appear to be no reason why this cannot be achieved.

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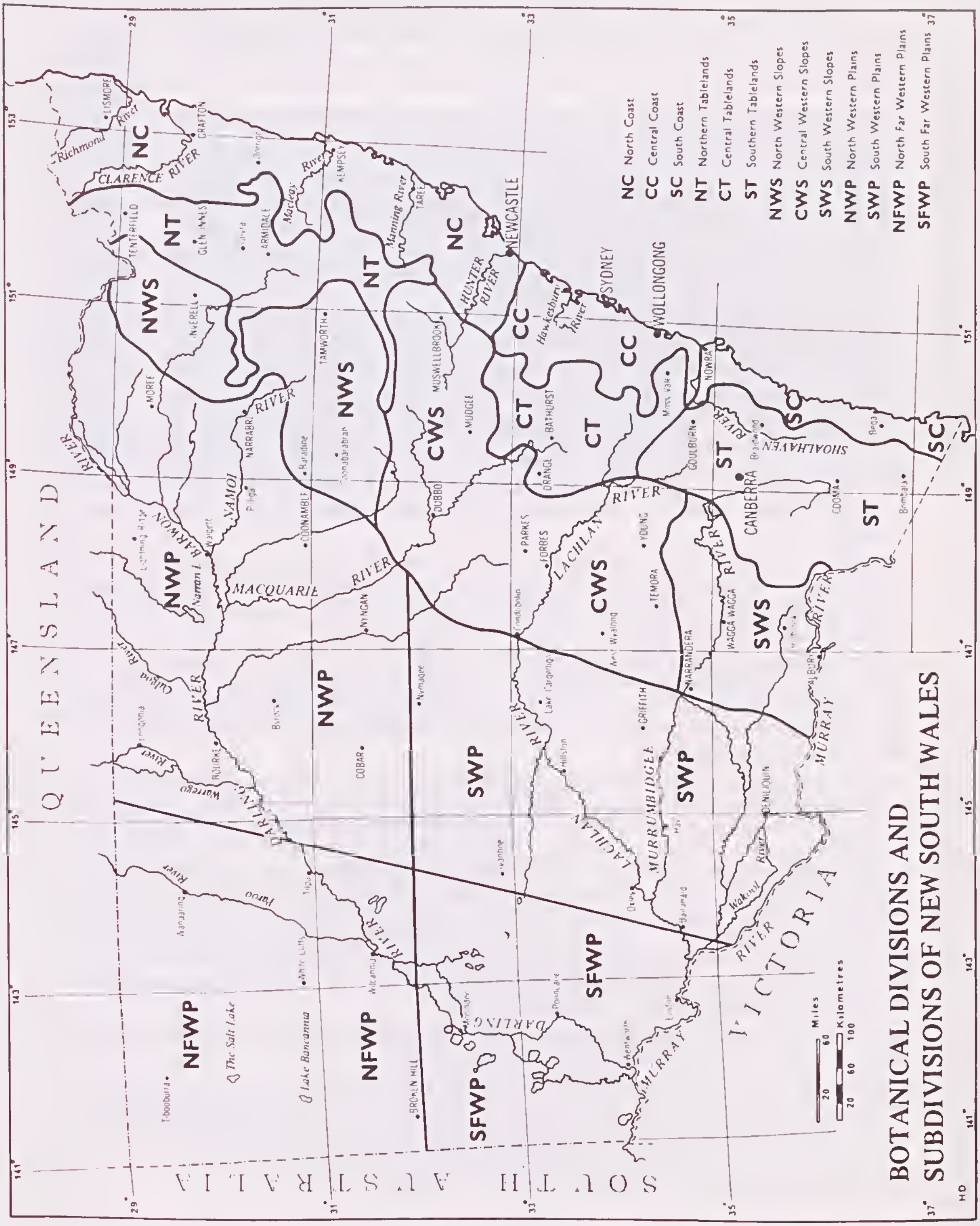


For explanation and description of the Botanical Divisions and Subdivisions of New South Wales see Anderson, R. H. (1961). Introduction. *Contr. New South Wales Natl. Herb. Fl. New South Wales* Nos 1–18, pp. 1–15.

INFORMATION FOR AUTHORS

Cunninghamia is published annually in July. Papers dealing with all aspects of plant ecology, in particular vegetation mapping and plant community dynamics are welcome to be considered for publication. Papers dealing primarily with New South Wales or with comparative data from New South Wales and neighbouring states will be given preference. Brief papers may be published as Short Communications (see previous issues for format).

The deadline for the submission of papers is **1 October** for publication in the following year. Authors are expected to have had their papers peer-reviewed before submission. All papers will be refereed. Two copies of the manuscript should be submitted along with originals of photographs and clear photocopies of all other figures. The full postal address (plus telephone and fax numbers) of the author who will check the proofs and receive correspondence should be included. Once a paper has been accepted for publication the author should provide the paper on a computer disk along with the final artwork for figures etc. The disk should be in IBM compatible (MS-DOS) or Macintosh format and clearly labelled with the word processing program used and the file name(s).

Organisation of the paper The title should be explicit and descriptive of the content; a short running title and an abstract (except for Short Communications) should be included. Check most recent issue for format. It would be helpful if authors could indicate in the margin the relative importance of the headings.

General formatting requirements • Text should be flush left. This applies also for abstracts, headings, keys and reference lists. Headings should be in upper and lower case, and not underlined. • Use only a single space after *all* punctuation marks including full stops. • Insert a space between a numeral and unit of measurement, e.g. 3 km, but no space between initials, e.g. L.A.R. Haegi, or between a hyphen and associated numerals, e.g. 5.2-6 mm. • Do not use the space-bar to indent or tabulate. •Underline, in preference to italics, and use single quote marks before double. • Species lists should be in one column, flush left.

Abbreviations, units etc. SI units (metre, kilogram etc.) are to be used. Statistics and measurements should always be given as figures, e.g. 10 mm, except where the number begins the sentence. *The Macquarie Dictionary*, latest edition, and the *Style Manual for Authors, Editors and Printers*, 4th edn, AGPS, 1988, should be consulted for spelling, abbreviations and other conventions.

References References in the text should be made by giving the author's name with the year of publication in parentheses. For reference list at end of paper see papers in this issue for style. If several papers by the same author and from the same year are cited, *a*, *b*, *c*, should be put (in italics) after the year of publication. Titles of journals should be given in full or abbreviated in accordance with the latest (4th) edition of the *World List of Scientific Periodicals*.

Illustrations/maps/photos • In general figures should be drawn one and a half times the final printed size. Check that line thickness and evenness, and labelling size are suitable for the final reproduction size and that maps show their context clearly (by lat./long. or an inset map) and that relevant place names in the text (but not for cited specimens) are shown. • Submit line drawings as bromide (Repromaster) copies with the final manuscript. • Photos should be unmounted, good-quality gloss prints, with self-adhesive labels on back indicating number, author and top of photo. • Labelling that is part of an illustration, e.g. place names on a map, should be added by the person preparing the illustration. • Bar scales for maps and photographs are preferred to numerical scales. • Bear in mind the shape of the final printed page and that the maximum final size of the illustration is 205 mm high x 125 mm wide, but preferably less to leave space for a caption on the same page. • Authors wishing to submit large or complex maps should discuss cartography with the editors before final preparation.

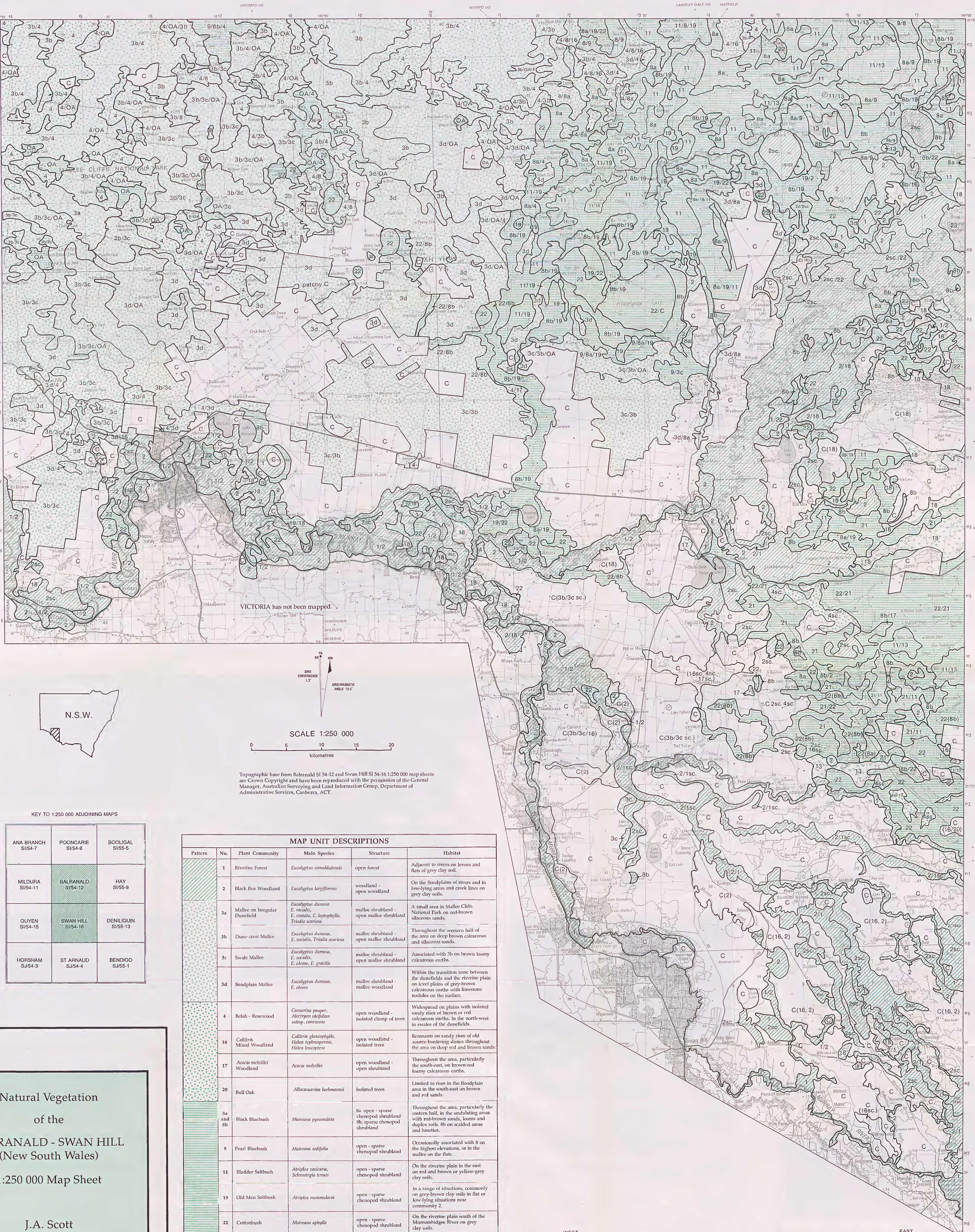
Captions Use lower case letters for the parts of a figure e.g. **Figure 1.** The plant communities of Bents Basin showing **a**, Forest Hill Creek section and **b**, Little Mountain section.

Tables should preferably be portrait rather than landscape shape i.e. taller rather than wider. They should be typed as separate files. Column headings should be brief with units of measurement in parentheses. Each table must be referred to in the text and its approximate position should be indicated in the margin of the manuscript. Please remember that tables need to fit into the journal page size.

More detailed instructions are available on request from the editors.

BALRANALD - SWAN HILL

1:250 000 VEGETATION SERIES


MALLEE CLIFFS NATIONAL PARK
VICTORIA has not been mapped.
TN
GN
MN
GRID CONVERGENCE 1.3°
GRID/MAGNETIC ANGLE 10.6°
N.S.W.

SCALE 1:250 000

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kilometres

Topographic base from Balranald SI 54-12 and Swan Hill SI 54-16 1:250 000 map sheets are Crown Copyright and have been reproduced with the permission of the General Manager, Australian Surveying and Land Information Group, Department of Administrative Services, Canberra, ACT.

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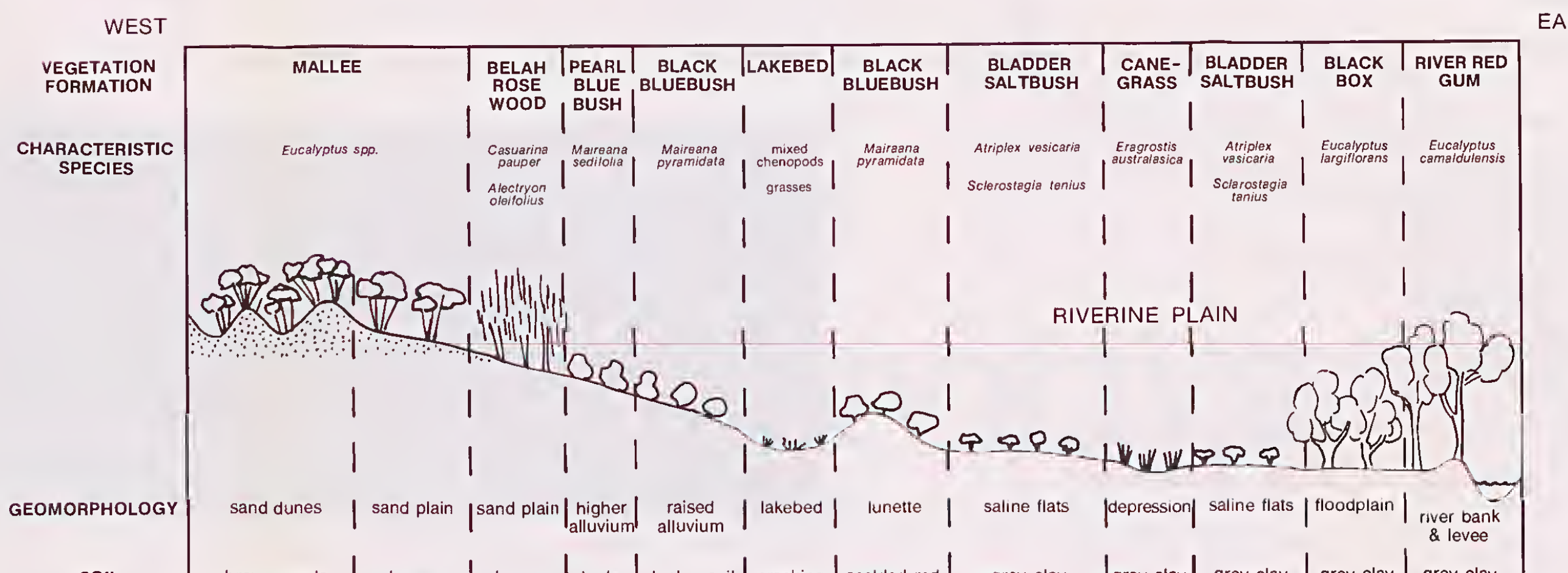
ANA BRANCH SI/54-7	POONCARIE SI/54-8	BOOLIGAL SI/55-5
MILDURA SI/54-11	BALRANALD SI/54-12	HAY SI/55-9
OUYEN SI/54-15	SWAN HILL SI/54-16	DENILIQUIN SI/55-13
HORSHAM SJ/54-3	ST ARNAUD SJ/54-4	BENDIGO SJ/55-1

MAP UNIT DESCRIPTIONS

Pattern	No.	Plant Community	Main Species	Structure	Habitat
▨	1	Riverine Forest	*Eucalyptus camaldulensis*	open forest	Adjacent to rivers on levees and flats of grey clay soil.
▨	2	Black Box Woodland	*Eucalyptus largiflorens*	woodland - open woodland	On the floodplains of rivers and in low-lying areas and creek lines on grey clay soils.
	3a	Mallee on Irregular Dunefield	*Eucalyptus dumosa* *E. socialis*, *E. costata*, *E. leptophylla*, *Triodia scariosa*	mallee shrubland - open mallee shrubland	A small area in Mallee Cliffs National Park on red-brown silaceous sands.
	3b	Dune-crest Mallee	*Eucalyptus dumosa*, *E. socialis*, *Triodia scariosa*	mallee shrubland - open mallee shrubland	Throughout the western half of the area on deep brown calcareous and silaceous sands.
	3c	Swale Mallee	*Eucalyptus dumosa*, *E. socialis*, *E. oleosa*, *E. gracilis*	mallee shrubland - open mallee shrubland	Associated with 3b on brown loamy calcareous earths.
	3d	Sandplain Mallee	*Eucalyptus dumosa*, *E. oleosa*	mallee shrubland - mallee woodland	Within the transition zone between the dunefields and the riverine plain on level plains of grey-brown calcareous earths with limestone nodules on the surface.
	4	Belah - Rosewood	*Casuarina pauper*, *Alectryon oleifolius* subsp. *canescens*	open woodland - isolated clump of trees	Widespread on plains with isolated sandy rises of brown or red calcareous earths. In the north-west in swales of the dunefields.
	16	*Callitris* Mixed Woodland	*Callitris glaucophylla*, *Hakea tephrosperma*, *Hakea leucoptera*	open woodland - isolated trees	Remnants on sandy rises of old source-bordering dunes throughout the area on deep red and brown sands.
	17	*Acacia melvillei* Woodland	*Acacia melvillei*	open woodland - open shrubland	Throughout the area, particularly the south-east, on brown-red loamy calcareous earths.
	20	Bull Oak	*Allocasuarina luehmannii*	isolated trees	Limited to rises in the floodplain area in the south-east on brown and red sands.
	8a and 8b	Black Bluebush	*Maireana pyramidata*	8a. open - sparse chenopod shrubland 8b. sparse chenopod shrubland	Throughout the area, particularly the eastern half, in the undulating areas with red-brown sands, loams and duplex soils. 8b on scalded areas and lunettes.
	9	Pearl Bluebush	*Maireana sedifolia*	open - sparse chenopod shrubland	Occasionally associated with 8 on the highest elevations, or in the mallee on the flats.
	11	Bladder Saltbush	*Atriplex vesicaria*, *Sclerostegia tenuis*	open - sparse chenopod shrubland	On the riverine plain in the east on red and brown or yellow-grey clay soils.
	19	Old Man Saltbush	*Atriplex nummularia*	open - sparse chenopod shrubland	In a range of situations, commonly on grey-brown clay soils in flat or low-lying situations near community 2.
	21	Cottonbush	*Maireana aphylla*	open - sparse chenopod shrubland	On the riverine plain south of the Murrumbidgee River on grey clay soils.
	22	Dillon bush	*Nitraria billardieri*	sparse shrubland	In disturbed areas on plains, floodplains and dry lakebeds on clay and loam soils often saline.
	OA	Open Areas	various shrubs and grasses	sparse chenopod shrubland - grassland	Areas of heavier soil within the mallee often along natural drainage lines, or disturbed areas.
	13	Canegrass	*Eragrostis australasica*	grassland	In low-lying depressions on the riverine plain on grey clay soils.
	18	Lignum	*Muehlenbeckia florulenta*	shrubland - open shrubland	On river floodplains where grey clay soils are infrequently flooded.
	23	Great Cumbung Swamp	*Phragmites australis* *Senecio cunninghamii*	closed - open herbland	On the eastern edge of the area within the floodplain on heavy clay soils.
	C	Cleared and/or cropped	Native vegetation has largely been removed for agricultural or urban development but remnant vegetation of varying sizes and condition may remain. Where possible pre-cleared vegetation and remnants have been indicated in brackets following C.		
	sc.	scattered	Trees are scattered.		

Present day vegetation as of Jan 1991. Clearing marked from LANDSAT Jan 1991.



	MALLEE		BELAH ROSE WOOD	PEARL BLUE BUSH	BLACK BLUEBUSH	LAKEBED	BLACK BLUEBUSH	BLADDER SALTBUSH	CANE-GRASS	BLADDER SALTBUSH	BLACK BOX	RIVER RED GUM
CHARACTERISTIC SPECIES	*Eucalyptus spp.*		*Casuarina pauper* *Alectryon oleifolius*	*Maireana sedifolia*	*Maireana pyramidata*	mixed chenopods grasses	*Mairaana pyramidata*	*Atriplex vesicaria* *Sclerostagia tenius*	*Eragrostis australasica*	*Atriplex vasicaria* *Sclarostagia tanius*	*Eucalyptus largiflorans*	*Eucalyptus camaldulensis*
GEOMORPHOLOGY	sand dunes	sand plain	sand plain	higher alluvium	raised alluvium	lakebed	lunette	saline flats	depression	saline flats	floodplain	river bank & levee
SOIL	brown sands & loams	brown calcareous earths	brown calcareous earths	duplex soil	duplex soil	cracking grey clay	scalded red & grey clay	grey clay	grey clay	grey clay	grey clay	grey clay

Schematic profile diagram showing relative changes in the landscape of the mapped area from west to east.

Natural Vegetation

of the

BALRANALD - SWAN HILL
(New South Wales)

1:250 000 Map Sheet

J.A. Scott

Descriptions of the plant communities are given in Cunninghamia 2(4) 1992

Compiled and prepared at the
National Herbarium of New South Wales

Royal Botanic Gardens Sydney

Understanding the ecology of our native plants

PLANT COMMUNITIES OF THE
BALRANALD - SWAN HILL 1:250 000 MAP SHEET

Community 1 Riverine Forest

Structure: open forest * & **

Characteristic species	**Associated species**
Eucalyptus camaldulensis	*Muehlenbeckia florulenta,*
(River Red Gum)	*Wahlenbergia fuminalis, Paspalidium jubiflorum*
	Acacia stenophylla, Eucalyptus largiflorens
	Cynodon dactylon, Ranunculus lappaceus
	Brachycome basaltica var. *gracilis*

On the extensive floodplain of the Murrumbidgee River two subunits have been described by Pressey *et al.* (1984).

Levees	**Floodplain**
Eucalyptus camaldulensis	*Eucalyptus camaldulensis*
Carex appressa	*Marsilea drummondii, Phragmites australis*
**Cirsium vulgare*	*Eragrostis australasica, Centipeda minima*
Wahlenbergia fluminalis	*Pratia concolor, Ranunculus lappaceus*
Pratia concolor	*Chenopodium nitrariacium*
Paspalidium jubiflorum	*Atriplex nummularia*
**Sonchus oleraceus*	

Soils: levees of grey, massive, non-cracking clays; at low elevations strongly gilgaid, grey self-mulching clays to massive non-cracking clays near the top of the floodplain (Pressey *et al.* 1984).
Occurrence: This community is found on the banks nearest the channels of the major rivers and creeks throughout the region, and on low-lying flats subject to flooding. The largest area of this community is found in the Lowbidgee District along the Murrumbidgee River. The densest stands of this community are along the banks nearest the river channels. Extensive areas on the flats have a more "open woodland" structure. For the length of the Murrumbidgee River within the mapped area, Black Box *Eucalyptus largiflorens* usually occurs as an adjacent community (2) on the floodplain flats. On parts of the Murray River the floodplain is much narrower and often the River Red Gum forest is abruptly bounded by higher ground of red/brown earths supporting mallee or *Callitris* mixed woodland, much of which has been cleared. This is most apparent along the stretch of the Murray River between the points of entry of the Wakool and Murrumbidgee Rivers.

Community 2 Black Box

Structure: woodland *, woodland - open woodland **

Characteristic species	**Associated species**
Eucalyptus largiflorens	*Chenopodium nitrariacium*
	Atriplex nummularia, Muehlenbeckia florulenta
	Enchylaena tomentosa, Sclerolaena tricuspis
	Einadia nutans, often with *Atriplex lindleyi,*
	Chamaesyce drummondii

Soils: Grey clays rarely cracking and with a flat or gently undulating surface.
Occurrence: Throughout the region on the uppermost level of the floodplain; beyond the floodplain it may occur in depressions along creeks, drains and old stream beds (eg. Box Creek), and fringing ephemeral lakes. Examples of this community include Yanga Nature Reserve, the floodplain just west of Euston on the south side of the Sturt Highway, and ringing many of the lakes such as Lake Marimley, Lake Talbetts, Harveys Lake and Chillichil Lake.

Community 3 Mallee

3a Mallee on Irregular Dunefield

Structure: tall shrubland *; mallee shrubland - open mallee shrubland **

Characteristic species	**Associated species**
Eucalyptus dumosa, E. socialis,	*Olearia muelleri, Grevillea huegelii,*
E. costata, E. leptophylla	*Acacia colletioides,*
E. oleosa, Triodia scariosa	*Bossiaea walkeri*

Soils: Deep red-brown siliceous sands (Eldridge 1985).
Occurrence: The only area is in Mallee Cliffs National Park just north of Chalky Tank; it occurs more commonly to the north on the Pooncarie map.

3b Dune-crest Mallee

Structure: tall shrubland *; mallee shrubland - open mallee shrubland **

Characteristic species	**Associated species**
Eucalyptus socialis,	*Olearia pimelioides, Acacia colletioides*
Eucalyptus dumosa,	*Dodonaea viscosa* subsp. *angustissima*
Eucalyptus gracilis,	*Eremophila glabra, Eucalyptus costata,*
Triodia scariosa	*Senna artemisioides* subsp. *filifolia,*
	Chenopodium curvispicatum
	Maireana pentatropis, Westringia rigida,
	Myoporum platycarpum, occasional
	Callitris verrucosa.

Soils: Deep brown calcareous and siliceous sands (Eldridge 1985).
Occurrence: Throughout the western half of the map sheet on the aeolian sands. In the north-west it is associated with Belah - Rosewood woodland (community 4) which occurs in the swales. This pattern is more common on the Ana Branch map sheet in the north-west, mapped as unit 5 by Fox (1991).

3c Swale Mallee

Structure: tall shrubland *; mallee shrubland - open mallee shrubland **

Characteristic species	**Associated species**
Eucalyptus dumosa,	*Enchylaena tomentosa, Maireana pentatropis,*
Eucalyptus socialis,	*Maireana sclerolaenoides,*
Eucalyptus oleosa,	*Atriplex stipitata, Zygophyllum apiculatum,*
Eucalyptus gracilis	*Zygophyllum aurantiacum, Westringia rigida,*
	Senna artemisioides subsp. *filifolia,*
	Sclerolaena obliquicuspis,
	Acacia colletioides,
	Dodonaea viscosa subsp. *angustissima.*

Soils: Brown loamy calcareous earths (Eldridge 1985).
Occurrence: Throughout the dune fields on the western half of the map sheet associated with the Dune-Crest Mallee community 3b, particularly south of the mosaic pattern of 3b/4. Isolated Belah *(Casuarina pauper)* occurs in some of the swales.

3d Sandplain Mallee

Structure: tall shrubland *; mallee shrubland - mallee woodland **

Characteristic species	**Associated species**
Eucalyptus dumosa	*Atriplex stipitata, Zygophyllum apiculatum,*
Eucalyptus oleosa	*Zygophyllum aurantiacum,*
	Maireana pyramidata, Maireana pentatropis,
	Maireana spp., *Enchylaena tomentosa,*
	Sclerolaena obliquicuspis,
	Chenopodium curvispicatum,
	**Psilocaulon tenue, Dissocarpus paradoxus,*
	some *Eucalyptus gracilis*

Soils: Grey-brown loam to clay-loam calcareous earths on extensive level plains often with limestone nodules on the surface (Eldridge 1985).
Occurrence: Within the transition zone between aeolian and alluvial landscapes, on southern part of the Willandra Lakes system. Flat plains with no dunes.

Community 4 Belah - Rosewood

Structure: woodland *; open woodland - isolated clumps **

Characteristic species	**Associated species**
Casuarina pauper	*Exocarpos aphyllus, Olearia muelleri,*
Alectryon oleifolius	*Myoporum platycarpum,*
subsp. *canescens*	*Enchylaena tomentosa, Einadia nutans,*
	Sclerolaena spp., *Maireana* spp.
	Geijera parviflora in the larger stands
	in the north.

Soils: Brown calcareous earths on plains with isolated sandy rises; deep brown and red loam to loamy sands.
Occurrence: This woodland is widespread throughout the mapped area. In the far north of the map in the mallee sand - dune country it occurs in the low lying areas of the swales where the soil is heavier. These areas were too small to map separately but due to their consistent recurring pattern are shown as a mosaic unit (mapped as 3b/4). This unit is more extensive to the north-west of the map on the Ana Branch - Mildura sheet (Fox 1991).
Larger areas of this community have been delineated, such as the band to the north-west of 'Bidura'. Much of this has been cleared for crops. This was also the case further south in the Sandplain Mallee, unit 3d, just north of the Sturt Highway. It is also associated with old lake and river systems in the north-east of the map, often seen with *Callitris* Mixed Woodland in undulating country.
Dotted in the south-east on heavy clay soils associated with the floodplains between the Murrumbidgee and Edward Rivers in close proximity to unit 2, *Eucalyptus largiflorens*, Belah (*Casuarina pauper*) dominates the groves, many of which are cleared or thinned. With further sampling this may be seen as a separate unit from that in the north.

Community 8 Black Bluebush

Structure: low shrubland - low open shrubland *; open chenopod shrubland - sparse chenopod shrubland **

8a.**Characteristic species**	**Associated species**
Maireana pyramidata	*Rhagodia spinescens, Enchylaena tomentosa,*
	Atriplex spp., *Sclerolaena* spp.,
	Stipa nodosa, Stipa elegantissima, annuals.

8b. = same community as above but a more sparse shrubland usually on scalded areas often associated with areas along old stream beds and lunettes, or areas that have been particularly overgrazed and/or cleared.

Soils: Red-brown sand and loam duplex soils. Deep sandy soils in which limestone exists at a greater depth than 1.2 m below the surface (Beadle 1948).
Occurrence: This community occurs throughout the whole map area, most common in the transition zone between the aeolian sand dune country and the riverine plain. It is closely associated with lunettes and source bordering dunes of old river systems. The best stands are in the north-east corner of the map through to the boundary with the mallee country to the west. However, it also occurs south-east of Balranald. It may occur as the understorey of an adjacent woodland, such as Belah - Rosewood *Casaurina pauper - Alectryon oleifolius* subsp. *canescens* (community 4) near 'Prungle', or of mallee such as on the Prungle Mail road.

Community 9 Pearl Bluebush

Structure: low shrubland *; open - sparse chenopod shrubland **

Characteristic species	**Associated species**
Maireana sedifolia	*Enchylaena tomentosa, Rhagodia spinescens,*
	Stipa elegantissima, Maireana pyramidata.

Soils: Red-brown sand or loam duplex soils. Deep sandy soils in which limestone exists less than 60 cm below the surface (Beadle 1948).
Occurrence: Closely associated with Black Bluebush (*Maireana pyramidata*) (community 8) usually on slightly higher ground, such as on the crest of rises in the undulating country in the north-east sector of the map. Occasionally occurs in open areas within the mallee country such as to the north of and along the eastern boundary of Mallee Cliffs National Park.

Community 11 Bladder Saltbush with *Sclerostegia tenuis*

Structure: low shrubland *; open - sparse chenopod shrubland **

Characteristic species	**Associated species**
Atriplex vesicaria,	*Malacocera tricornis, Disphyma clavellatum,*
Sclerostegia tenuis	*Dissocarpus biflorus* var. *biflorus,*
	Brachycome trachycarpa, annuals such as
	Plantago drummondii, Senecio glossanthus,
	Brachycome lineariloba, Rhodanthe corymbiflora,
	**Lamarckia aurea, *Bromus rubens*

Soils: Red and brown or yellow-grey compact clay or clay-loam soils.
Occurrence: In the eastern half of the region, the vastest areas in the north. It is often broken by areas of *Maireana pyramidata* (community 8) and *Atriplex nummularia* (community 19).

Community 13 Canegrass

Structure: grassland * & **

Characteristic species	**Associated species**
Eragrostis australasica	*Eleocharis pallens, Juncus aridicola,*
	Juncus flavidus, Muehlenbeckia florulenta

Soils: Slightly saline, compact heavy grey clay soils on which water is ponded for several months (Cunningham 1981).
Occurrence: Generally throughout the eastern-half of the area in low-lying areas of swamps, table-drains and claypans within the chenopod shrubland communities 11 and 21. Typically occurring in small depressions (each one unmappable at this scale) within *Atriplex vesicaria - Sclerostegia tenuis* shrublands (community 11) in the north-east of the map. Areas with the highest occurrence of Canegrass depressions have been mapped as a mosaic unit 11/13. Also occurs along the old creek line of Box Creek on the Prungle Mail road. It is seen in larger stands south-west of Perekerten and may grow with Lignum and in the riverine communities.

Community 16 *Callitris* Mixed Woodland

Structure: open woodland *; open woodland - isolated trees **

Characteristic species	**Associated species**
Callitris glaucophylla,	*Eremophila longifolia,*
Hakea leucoptera,	*Dodonaea viscosa* subsp. *angustissima,*
Hakea tephrosperma	*Pittosporum phillyreoides*, also at times
	with *Alectryon oleifolius* subsp. *canescens,*
	Casuarina pauper or *Allocasuarina luehmannii,*
	Acacia melvillei, Geijera parviflora.

Near the Murray River *Callitris preissii* subsp. *murrayensis* may replace *Callitris glaucophylla.*

Soils: Deep coarse textured red and brown sands and sand-loams.
Occurrence: Usually as remnants on elevated red sandy ridges occurring throughout the region, usually corresponding to old source bordering dunes of prior streams and lakes. More common in the south-east such as near Condoulpe Lake south of Balranald, though much of this has been cleared. One of the best remnants is 2 km north-east of 'Lyle' but this would have been more extensive in the past. Raised areas of old lunette remnants on the Murrumbidgee floodplain have remnants of this community often with *Maireana pyramidata*. These areas have been heavily grazed and much of the previous shrubs have been removed (Pressey *et al.* 1984).
Callitris glaucophylla with or without associated species may occur in association with Belah - Rosewood (community 4) in the mallee dune country and the undulating country in the north to the Balranald - Ivanhoe road.

Community 17 *Acacia melvillei* Woodland

Structure: tall shrubland - low woodland *; open woodland - open shrubland **

Characteristic species	**Associated species**
Acacia melvillei	*Enchylaena tomentosa, Sida corrugata,*
	Rhagodia spinescens, Nitraria billardieri
	Medicago spp., *Tetragonia tetragonioides,*
	Goodenia fascicularis & Zygophyllum spp.

Soils: Brown-red loamy calcareous earths.
Occurrence: *Acacia melvillei* may form groves as a single dominant species. The largest of these is located just to the south and the north of the town of Balranald, where they are large enough to be mapped as a separate unit. Grazing of stock and rabbits resulted in a sparse understorey. Some resprouting of the acacias occurs, but generally very little regeneration is to be seen at present.
Groves of smaller size occur throughout the area, less so in the mallee of the north-west. *Acacia melvillei* also appears dotted throughout the south-east of the map area, often as one or two trees, possibly remnants of once larger areas that have been cleared or grazed.

Community 18 Lignum

Structure: open scrub *; shrubland - open shrubland **
This unit was not sampled, so information has been taken from literature.

Murray River floodplain	**Murrumbidgee (Pressey *et al.* 1984)**
(Margules & Partners *et al.* 1990)	*Muehlenbeckia florulenta*, **Medicago* spp.,
Muehlenbeckia florulenta,	*Senecio cunninghamii*, **Phalaris paradoxa*
*Einadia nutans, *Bromus rubens,*	
with or without	
Chenopodium nitrariaceum	

Soils: Strongly gilgaied, grey self-mulching clay soils (Pressey *et al.* 1984)
Occurrence: This community generally occurs on the floodplains at a higher elevation than *Eucalyptus camaldulensis* around the fringes of grey soil open country (Pressey *et al.* 1984). It is most abundant in Lowbidgee Area, under River Red Gum (*Eucalyptus camaldulensis*) and Black Box (*Eucalyptus largiflorens*) or as vast areas of monospecific stands. On the road to 'Yanga' much of the Lignum has been cleared for cropping.

Community 19 Old Man Saltbush

Structure: low shrubland *; open - sparse chenopod shrubland **

Characteristic species	**Associated species**
Atriplex nummularia	*Atriplex vesicaria, Rhagodia spinescens*
	Atriplex spp., *Sclerolaena* spp.

Soils: Mostly on grey and brown clay soils, usually in flat or low-lying situations. Can be found on practically all soils and at all levels (Cunningham *et al.* 1981).
Occurrence: Throughout the mapped area except the mallee, in a range of situations. Most often on grey clay soils near *Eucalyptus largiflorens* woodlands and along drainage lines. The largest areas are just north of Yanga Nature Reserve and south of Waldaira Lake. It also occurs on red-brown earths in other chenopod shrublands such as communities 8, Black Bluebush and 11, Bladder Saltbush with *Sclerostegia*, throughout the north-east sector of the map, for example on the Ivanhoe road north of Box Creek and along the old drainage line of Box Creek following Prungle Mail road, though separate populations are too small to map.

Community 20 Bull Oak

Structure: open woodland *; isolated plants - isolated clumps **

Characteristic species
Allocasuarina luehmannii

Soils: Deep brown and red sands and sand-loam.
Occurrence: This community is found on sandy rises in the south-east of the map. Usually it is seen as a few single trees, rarely in groves as in *Casuarina pauper* and usually in association with *Callitris preissii* subsp. *murrayensis*. It is more frequent further east and thought to have originally occurred in association with *Callitris* which has been removed for fencing and building purposes (Cunningham *et al.* 1981). An example in the mapped area is near 'Lyle' south-east of Balranald in the *Callitris* Mixed Woodland mentioned in the description for community 16. Isolated trees are found on the corner of the Swan Hill and Moulamein roads south of Balranald. Also present here is Wilga (*Geijera parviflora*), *Acacia oswaldii* and *Callitris preissii* subsp. *murrayensis* and mallee nearby. This community was not extensive enough to be mapped as a separate unit.

Community 21 Cottonbush

Structure: low shrubland *; open - sparse chenopod shrubland **

Characteristic species	**Associated species**
Maireana aphylla	*Atriplex vesicaria, Atriplex leptocarpa,*
	Nitraria billardieri, Sclerolaena spp.
	Calocephalus sonderi, Rhodanthe stuartiana,
	**Cotula bipinnata.*

Soils: Yellow-grey and grey clay soils.
Occurrence: Restricted to the south-eastern corner of the map on flat plain country south of the Murrumbidgee River, for example along the Keri Keri Rd.

Community 22 Dillon Bush

Structure: low - low open shrubland *, sparse shrubland **

Characteristic species
Nitraria billardieri

This community usually occupies a disturbed area and can occur within most communities as a result of overgrazing or clearing. Associated species vary depending on the original vegetation. Usually there is a high percentage of grasses, weeds and annuals with the occasional shrub for example, *Einadia nutans, Sclerolaena* spp., *Atriplex* spp. Annual grasses and Asteraceae commonly occur. *Nitraria billardieri* may be only present as an occasional shrub.

Soils: Usually clay and loam soils, often saline areas. In the Lowbidgee the soils are strongly gilgaied grey self-mulching clays (Pressey *et al.* 1984).
Occurrence: On plains and floodplains throughout the region, predominantly in the east, such as dry lakebeds that have been grazed or left after cropping, overgrazed areas, and previously cropped areas.

Community 23 Great Cumbung Swamp

This unit was not sampled and is taken from Pressey *et al.* (1984).

Structure: closed - open herbland *; closed - open grassland/forbland **

Characteristic species	**Associated species**
Phragmites australis	*Paspalum distichum, *Cirsium vulgare,*
Senecio cunninghamii	*Pratia concolor,* often with
	**Hordeum leporinum & *Polypogon monspeliensis.*

Within this unit *Senecio cunninghamii* occurs on the higher ground on the edge of the swamp, with *Phragmites australis* in the swales and down to the upper limit of *Typha orientalis* which grows in the water.

Soils: Heavy clay soils.
Occurrence: In the Great Cumbung swamp at the far eastern edge of the map.

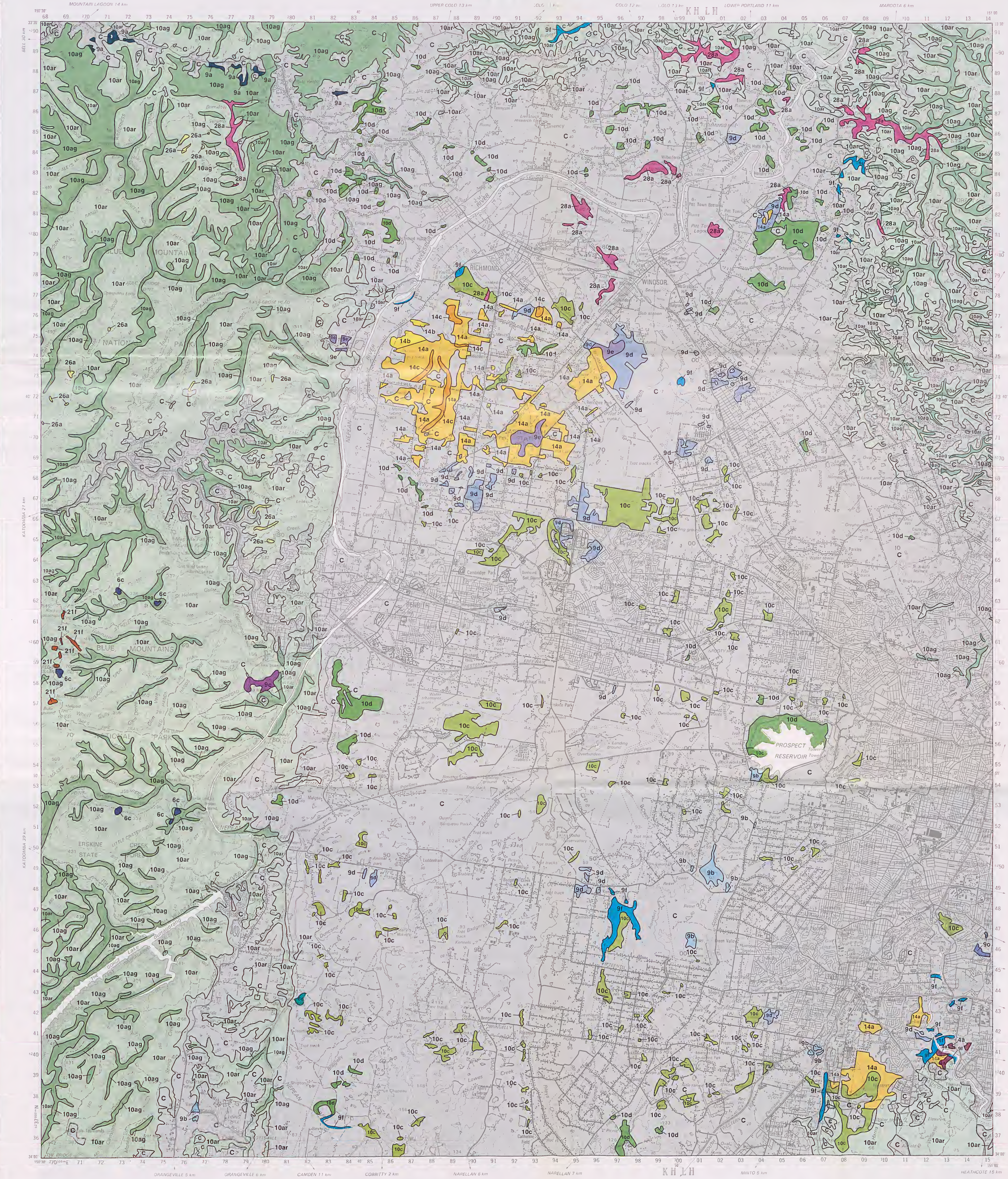
OA Open Areas

"OA" indicates "open areas" occurring mostly on the aeolian soils of the mallee country. They are thought to be naturally occurring areas of heavier soil (Eldridge pers. comm.) supporting shrubs, herbs and grasses. Within the Sandplain Mallee many of the "open areas" follow old drainage lines. Within Mallee Cliffs National Park, Morcom and Westbrooke (1990) referred to these areas as "herbland - open herbland" resulting from the modification of chenopod shrublands or arid woodlands caused by grazing pressure.
Some of the less disturbed open areas to the north of and on the eastern boundary of Mallee Cliffs National Park support Pearl Bluebush (*Maireana sedifolia*) shrubland (community 9). Closer to tanks stocking pressure may have reduced many of these areas to predominantly grasslands. South of Mallee Cliffs National Park the open areas occasionally have patches of Belah, (*Casuarina pauper*).
Open areas in the mallee west of Euston are a result of frequent prescribed burning. Three fires in the space of seven years has led to a depletion of mallee in the swales creating open grasslands (Noble 1984).
Common species include *Sclerolaena obliquicuspis, Stipa nitida, Stipa nodosa*, often with *Dissocarpus paradoxa, Salsola kali*, and **Silene apetala.*

Vegetation Structure: Specht (1981) = *; Walker and Hopkins (1990) = **
* when placed before a species name, indicates the species is exotic.

PENRITH

1:100 000 VEGETATION SERIES

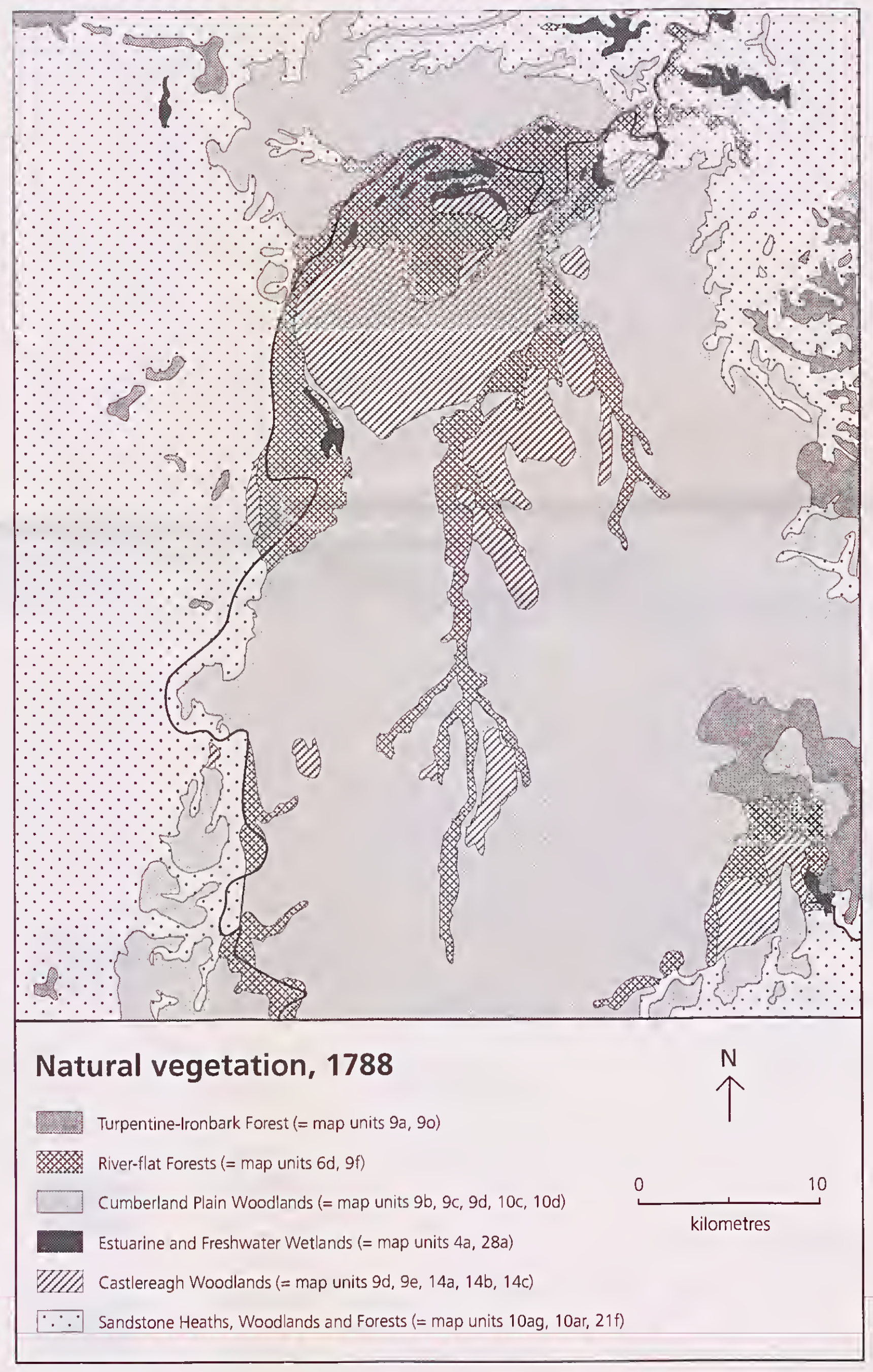


MAP UNIT DESCRIPTION

	MAP UNIT	STRUCTURE	MAIN CANOPY SPECIES	GEOLOGY	OCCURRENCE
🟪	4a	**Estuarine Complex**			
		Open-scrub	*Avicennia marina* *Aegiceras corniculatum*	Holocene alluvium	Estuarine mudflats regular tidal inundation
		Rushland/ Reedland	*Juncus kraussii* *Phragmites australis*		Infrequent inundation Brackish water
		Low open-forest	*Casuarina glauca*		
		Open-scrub	*Melaleuca ericifolia*		
🟪	6c	**Glen Forest**			
		Tall open-forest	*Eucalyptus deanei*	Diatremes	Isolated outcrops in Blue Mountains
🟦	6d	**Camden White Gum Forest**			
		Tall open-forest	*Eucalyptus benthamii*	Holocene alluvium	Confined to Nepean River at Bents Basin, Wallacia
🟦	9a	**Shale Cap Forest**			
		Open-forest	*Eucalyptus paniculata* *Eucalyptus notabilis*	Wianamatta Shale	Ridges along Bells road
🟦	9b	**Spotted Gum Forest**			
		Open-forest	*Eucalyptus maculata* *Eucalyptus moluccana*	Wianamatta Shale	On hills around Hoxton Park. Also around Werombi
🟪	9c	**Ironbark Forest**			
		Open-forest	*Eucalyptus crebra* *Eucalyptus fibrosa*	Wianamatta Shale	On shale remnants at Glenbrook
🟦	9d	**Shale/Gravel Transition Forest**			
		Open-forest	*Eucalyptus fibrosa* *Eucalyptus moluccana*	Wianamatta Shale/ Tertiary alluvium	On transition zone between these geological units
🟪	9e	**Castlereagh Ironbark Forest**			
		Open-forest	*Eucalyptus fibrosa*	Tertiary alluvium	Castlereagh area on clay soils
🟦	9f	**River-flat Forest**			
		Open-forest	*Angophora subvelutina* *Eucalyptus amplifolia* *Eucalyptus tereticornis*	Holocene alluvium	Alluvial flood plains along Nepean - Hawkesbury River and major tributary creeks
🟦	9o	**Turpentine-Ironbark Forest**			
		Open-forest	*Syncarpia glomulifera* *Eucalyptus paniculata*	Wianamatta Shale	Bankstown area
🟩	10ag	**Sydney Sandstone Complex** **Sydney Sandstone Gully Forest**			
		i) Tall open-forest	*Eucalyptus deanei* *or Eucalyptus saligna* *Angophora floribunda* *Syncarpia glomulifera*	Hawkesbury Sandstone/ Narrabeen Group	Sheltered gullies Hillsides Sheltered gorges
		ii) Closed-forest	*Ceratopetalum apetalum* *Doryphora sassafras*		
		iii) Open-forest	*Eucalyptus piperita* *Angophora costata* *+/- Eucalyptus pilularis*	Hawkesbury Sandstone	Gullies, sheltered hillsides

MAP UNIT DESCRIPTION

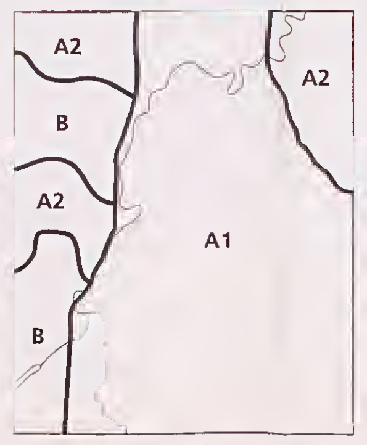
	MAP UNIT	STRUCTURE	MAIN CANOPY SPECIES	GEOLOGY	OCCURRENCE
⬜	10ar	**Sydney Sandstone Ridgetop Woodland**			
		i) Low open-forest	*Eucalyptus sieberi* *Eucalyptus piperita*	Hawkesbury Sandstone	Ridgetops and plateaus >1200mm pa rainfall
		ii) Woodland/ Open woodland	*Eucalyptus gummifera* *Eucalyptus eximia* *Eucalyptus sparsifolia* *Angophora costata* *Angophora bakeri*	Hawkesbury Sandstone	Ridges and dry exposed hillsides
		iii) Open-forest/ woodland	*Eucalyptus gummifera* *Angophora costata* *Eucalyptus notabilis* *Eucalyptus sparsifolia* *Eucalyptus punctata* *Syncarpia glomulifera*	Hawkesbury Sandstone with clay influence	Ridges
		iv) Open-scrub	*Angophora hispida*		Broad plateau surfaces
🟩	10c	**Grey Box Woodland**			
		Woodland	*Eucalyptus moluccana* *Eucalyptus tereticornis*	Wianamatta Shale	Flat to gently undulating basin of Cumberland Plain. Clay soils
🟩	10d	**Grey Box-Ironbark Woodland**			
		Woodland	*Eucalyptus moluccana* *Eucalyptus tereticornis* *Eucalyptus crebra*	Wianamatta Shale	Undulating to hilly country on margins of Cumberland Plain. Clay soils
🟨	14a	**Castlereagh Scribbly Gum Woodland**			
		Low woodland	*Eucalyptus sclerophylla* *Angophora bakeri*	Tertiary alluvium	Castlereagh-Londonderry and Holsworthy on sandy soils
🟨	14b	**Agnes Banks Woodland**			
		Low woodland/ open-scrub	*Eucalyptus sclerophylla* *Angophora bakeri* *Banksia serrata*	Tertiary alluvium	Confined to sand deposit at Agnes Banks
🟧	14c	**Swamp Woodland**			
		Low woodland	*Eucalyptus parramattensis*	Tertiary alluvium	Poorly drained depressions and creek lines
🟥	21f	**Lower Blue Mountains Heath**			
		Open-heath	*Eucalyptus stricta* *Allocasuarina nana*	Hawkesbury Sandstone	Dry, rocky ridge tops
🟨	26a	**Blue Mountains Sedge Swamps**			
		Closed-sedgeland	*Gymnoschoenus sphaerocephalus* *Lepidosperma limicola* *Xyris ustulata* *Baeckea linifolia*	Hawkesbury Sandstone	Poorly-drained sites on plateau
🟪	28a	**Freshwater Reed Swamps**			
		Open-sedgeland	*Eleocharis sphacelata* *Juncus usitatus* *Persicaria spp.*	Holocene alluvium	Freshwater swamps
⬜	C	**Cleared**	These areas are generally the better agricultural soils along the river alluvial flats or on the Wianamatta Shale country. Small remnants of native vegetation too small to show on the map may occur here.		



Natural vegetation, 1788

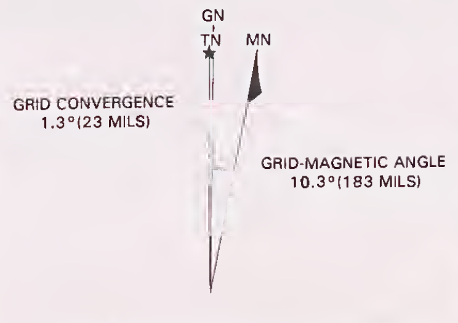
- ▨ Turpentine-Ironbark Forest (= map units 9a, 9o)
- ▩ River-flat Forests (= map units 6d, 9f)
- ░ Cumberland Plain Woodlands (= map units 9b, 9c, 9d, 10c, 10d)
- ■ Estuarine and Freshwater Wetlands (= map units 4a, 28a)
- ▧ Castlereagh Woodlands (= map units 9d, 9e, 14a, 14b, 14c)
- ⁘ Sandstone Heaths, Woodlands and Forests (= map units 10ag, 10ar, 21f)

Map Reliability



A1 Aerial photograph interpretation with extensive field reconnaissance.
A2 Aerial photograph interpretation with limited field reconnaissance.
B Aerial photograph interpretation only.

Aerial photography 1979, 1989.



GN
TN
MN
GRID CONVERGENCE 1.3°(23 MILS)
GRID-MAGNETIC ANGLE 10.3°(183 MILS)

TRUE NORTH, GRID NORTH AND MAGNETIC NORTH ARE SHOWN DIAGRAMMATICALLY FOR THE CENTRE OF THIS MAP. MAGNETIC NORTH IS CORRECT FOR 1975 AND MOVES EASTERLY BY 0.1°(2 MILS) IN ABOUT THREE YEARS.

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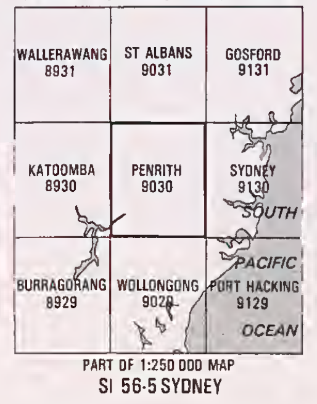

PART OF 1:250 000 MAP
SI 56-5 SYDNEY

Topographic base from Penrith 9030, 1:100,000 Map Sheet, Australian Surveying & Land Information Group, Department of Administrative Services. Thematic information drawn and colour separated by Cartoscope Pty Ltd and printed by Dynamic Press.

ELEVATION IN METRES. CONTOUR INTERVAL 20 METRES.

SCALE 1:100,000

Kilometres 2 0 2 4 6 8 10 Kilometres

NATURAL VEGETATION
# of the
PENRITH
area

D.H. Benson

Detailed descriptions of the plant communities are given in CUNNINGHAMIA Volume 2, Number 4, 1992

Compiled and prepared at the
NATIONAL HERBARIUM OF NEW SOUTH WALES,
ROYAL BOTANIC GARDENS, SYDNEY.

Understanding the ecology of our native plants.

Natural Vegetation

# of the

BALRANALD - SWAN HILL
(New South Wales)

CUNNINGHAMIA 2(4): 503-662 •1992

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